

A proposal to facilitate BIM implementation across the South African construction industry

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Abstract

The South African construction industry (SACI) is declining in growth and is facing many challenges. The global construction industry has realised the value of Building Information Modelling (BIM), and countries are facilitating BIM through national strategies and initiatives. However, the SACI lacks widespread and effective BIM adoption and implementation. Therefore, this study aimed to develop a proposal to facilitate BIM implementation across the SACI.

The literature review covered the theoretical background of BIM, a review of the related global and local literature, the challenges faced in South Africa regarding BIM implementation and the solutions proposed to mitigate these challenges. Then, an industry analysis was done covering the global BIM implementation strategies among six countries, followed by a discussion of the nature of the SACI. The methodology was qualitative and exploratory and entailed two main phases. Phase one entailed gaining knowledge about BIM in South Africa to select a focus group and develop an interview guide, forming a basis for the second phase. Phase two entailed conducting semi-structured interviews with nine BIM experts that have a profound understanding of the SACI. The interviews were analysed using thematic analysis to obtain the findings.

The challenges in the industry were found to be related to educational, cultural, legal, financial, and governmental aspects. A range of possible solutions was identified and themed: raising awareness, education and training, promoting pilot projects, developing standards, updating procurement systems, developing software that meets South African needs, and government initiatives. The main industry role-players regarding BIM implementation were divided into four industry groups: the government, the education sector, private organisations, and software developers. Guidance in terms of best practices regarding BIM implementation was found for South African firms. Five themes were identified for the guidelines. These are, determining the business value of BIM, developing a strategy to implement BIM in the organisation, acquiring external assistance, implementing sound change management practices, and initiating a pilot project.

Finally, a proposal was made to facilitate BIM implementation across the SACI, which entails three key concepts, namely, leadership, strategy, and roles and responsibilities. This research contributes to BIM development in the SACI and could be used for future research on national BIM implementation strategies.

Opsomming

Die Suid-Afrikaanse konstruksie bedryf (SAKB) is besig om negatief te groei en staan baie uitdagings in die gesig. Die globale konstruksie bedryf het reeds die waarde van Building Information Modelling (BIM) besef, en lande fasiliteer BIM deur nasionale strategieë en inisiatiewe. Die SAKB beleef egter nie wydverspreide en effektiewe BIM-aanneming en implementering nie. Hierdie studie het daarom ten doel om 'n voorstel te ontwikkel om BIM-implementering regoor die SAKB te fasiliteer.

Die literatuuroorsig dek die teoretiese agtergrond van BIM, gee 'n oorsig van die verwante globale en plaaslike literatuur, die uitdagings in Suid-Afrika met betrekking tot BIM-implementering en die voorgestelde oplossings om hierdie uitdagings te versag. 'n Industrie analyse word gedoen wat die globale BIM-implementering strategieë onder ses lande dek, gevolg deur 'n bespreking van die aard van die SAKB. Die metodologie van die studie was kwalitatief en verkennend en het twee hoof fases behels. Fase een het behels dat kennis oor BIM in Suid-Afrika opgedoen word om 'n fokusgroep te kies en 'n onderhoudsgids te ontwikkel, wat 'n basis vir die tweede fase vorm. Fase twee behels die uitvoer van semi-gestruktureerde onderhoude met nege BIM-kundiges wat 'n goeie begrip van die SAKB het. Die onderhoude is ontleed met behulp van tematiese analise om die bevindinge te verkry.

Daar is bevind dat die uitdagings in die bedryf verband hou met opvoedkundige, kulturele, wetlike, finansiële en regerings aspekte. 'n Verskeidenheid moontlike oplossings is geïdentifiseer met die volgende temas: bewustheid, opvoeding en opleiding, die bevordering van loodsprojekte, die ontwikkeling van standaarde, die opdatering van verkrygingstelsels, die ontwikkeling van sagteware wat aan Suid-Afrikaanse behoeftes voldoen, en regeringsinisiatiewe. Die belangrikste rolspelers in die bedryf ten opsigte van BIM-implementering is in vier bedryfsgroepe verdeel: die regering, die onderwyssektor, private organisasies en sagteware-ontwikkelaars. Riglyne in terme van beste praktyke rakende BIM-implementering is vir Suid-Afrikaanse maatskappye gevind. Vyf temas is vir die riglyne geïdentifiseer. Dit behels die bepaling van die besigheidswaarde van BIM, die ontwikkeling van 'n strategie om BIM in die organisasie te implementeer, om eksterne hulp te verkry, gesonde veranderings-bestuurspraktyke te implementeer, en om 'n loodsprojek te begin.

Ten slotte word 'n voorstel gemaak om BIM-implementering regoor die SAKB te fasiliteer, wat drie sleutel konsepte behels, naamlik leierskap, strategie, en rolle en verantwoordelikhede. Hierdie navorsing dra by tot BIM-ontwikkeling in die SAKB en kan gebruik word vir toekomstige navorsing oor nasionale BIM-implementering strategieë.

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List of abbreviations

2D	Two-dimensional
3D	Three-dimensional
ABAB	Australian BIM Advisory Board
AEC	Architecture Engineering and Construction
AECO	Architecture Engineering Construction and Operations
AIA	American Institute of Architects
AIR	Asset Information Requirements
ASAQS	Association of South African Quantity Surveyors
BAC	BIM Acceleration Committee
BBBEE	Broad-Based Black Economic Empowerment
BCA	Building Construction Authority
BEP	BIM Execution Plan
BIM	Building Information Modelling
BIS	Department of Business, Innovation and Strategy
CAD	Computer Aided Design
CAFM	Computer Aided Facility Management
CBE	Council for the Built Environment
CDE	Common Data Environment
CDP	Construction Digital Platform
CETA	Construction Education Training Authority
CGFCF	Construction Gross Fixed Capital Formation
CIDB	Construction Industry Development Board
CMMS	Computerized Maintenance Management System
COBie	Construction Operation Building information exchange
CORONET	Construction and Real Estate Network
CPD	Continuous Professional Development
CSF	Critical Success Factor
CVA	Construction Value Added
DIISRTE	Department of Industry, Innovation, Science, Research and Tertiary Education (Australia)
DPW	Department of Public Works
ECPMI	Ethiopian Construction Project Management Institute
EIR	Exchange Information Requirements
EPWP	Expanded Public Works Programme
FEC	Future Economy Council

FIDIC	Federation Internationale Des Ingenieurs Conseils
GCC	General Condition of Contracts
GDP	Gross Domestic Product
GSA	General Services Administration
IDD	Integrated Digital Delivery
IoT	Internet of Things
IP	Intellectual Property
IPD	Integrated Project Delivery
ISO	International Organisation of Standardisation
JBCC	Joint Building Contracts Committee
LEED	Leadership in Energy and Environmental Design
LOIN	Level Of Information Need
NBC	National BIM Council
NBIMS	National Building Information Modelling Standard
NBS	National Building Specification
NEC	New Engineering Contract
NDP	National Development Plan
NIBS	National Institute of Building Sciences
NZ	New Zealand
OIR	Organisational Information Requirements
PIR	Project Information Requirements
REC	Research Ethics Committee
RFI	Request For Information
ROI	Return On Investment
SA	South Africa
SAKB	Suid-Afrikaanse Konstruksie Bedryf
SANBC	South African BIM Council
SACAP	South African Council for Architecture Profession
SACI	South African Construction Industry
SAICE	South African Institution of Civil Engineering
SANBC	South African National BIM Council
SITA	State Information Technology Agency's
SME	Small and Medium Enterprise
UK	United Kingdom
US	United States
USA	United States of America

1 Introduction

1.1 Background

The world is transitioning into the fourth industrial revolution, which introduces trends in the construction industry such as automation, big data, cloud computing, smart cities and Internet of Things (IoT). The construction industry has a reputation for its slow uptake of technology compared to other industries such as manufacturing, agriculture and entertainment (Smith, 2014). However, developed countries such as the UK, USA and many others have recognised the economic benefit of using modern tools and processes in the construction industry (Jiang, Wu, Lei, *et al.*, 2021). Innovation increased performance and led to modern concepts such as lean construction practices, green construction, integrated project delivery, and full lifecycle asset management using digital twins (Osunsanmi, Aigbavboa & Oke, 2018).

A revolutionary moment in the construction industry was the introduction of Building Information Modelling (BIM). According to the International Organisation of Standardisation (ISO) 19650 standard, BIM is “*a shared digital representation of a built asset to facilitate design, construction and operation processes to form a reliable basis for decisions*” (The British Standards Institution, 2019). In simpler terms, a BIM model contains all information about a built asset (geometric data, non-geometric data, and all project-related documents), allowing for better decisions about the asset during the design, construction, and operational phases. However, the information that is contained in a BIM model needs to be reliable. Therefore, specific processes need to be implemented to manage the information flow and to ensure that the information is correct. BIM is therefore also regarded as a process of information management, and the acronym is often referred to as “Building Information Management”. Since the BIM process involves digitising information about buildings and civil engineering works, BIM has become a label or an insignia for digital transformation in the construction industry (National Building Specification, 2020).

The global Architecture, Engineering, Construction and Operations (AECO) industry has indeed recognised the value of BIM. Countries such as Denmark, Finland, Norway, Singapore, South Korea and the UK have already mandated BIM or have plans to mandate BIM for public projects (McGraw Hill Construction, 2014a). The latest National Building Specification (NBS) BIM report, based on roughly 1000 respondents from the UK, revealed that 73% of the respondents had used BIM in their projects in 2020, compared to 13% that used BIM in 2011 (National Building Specification, 2020). This rapid uptake of BIM is experienced worldwide, and many governments are driving the movement (Smith, 2014).

Global BIM adoption has increased over the past decade (National Building Specification, 2020). In addition, global digital transformation accelerated further in 2020 due to the Covid-19 pandemic, which forced people to work remotely and adopt digital processes (Savić, 2020). However, the rate of BIM adoption and digitalisation in the construction industry still varies rapidly from country to country and from organisation to organisation because of different cultures, government initiatives and a variation in the rate of the development of national BIM standards and guidelines (Akintola, Root & Senthilkumar, 2017; Edirisinghe & London, 2015). Countries such as the UK have strategies to facilitate BIM adoption and implementation, which involves government mandates, BIM standards, research and education programmes, and many institutions that provide BIM resources and training (HM Government, 2015; Royal Institution of Chartered Surveyors, 2020). However, other countries such as South Africa have yet to reach that level of BIM maturity (Akintola, Venkatachalam & Root, 2020; Govender, 2018; Mtya, 2019). Although a handful of larger AECO firms in South Africa have adopted some BIM solutions, BIM implementation is neither widespread nor optimal (Akintola *et al.*, 2017; Kiprotich, 2014; Mtya, 2019).

The South African government is the largest asset owner in South Africa, and they have not yet decided to mandate BIM or make BIM a requirement on public projects, as other governments have done. However, a national BIM mandate could be expected in the near future since there are movements in the government promoting digitalisation. An example is the release of the State Information Technology Agency's (SITA) 2020-2024 strategic plan, which emphasises the need for digitalisation and the use of modern technology such as cloud computing for government bodies (State Information Technology Agency, 2019). If the government decides to mandate BIM, then BIM competent organisations will be favoured with tender allocations. Froise (2014) confirmed that organisations willing to adopt and implement BIM would become more competitive than organisations reluctant to change. Regardless of when the government decides to mandate BIM, more organisations are implementing BIM, and change is happening (Mtya, 2019). If appropriately managed and facilitated, this change could have high economic potential for the industry and the country (McGraw Hill Construction, 2014a).

1.2 Problem statement and motivation

Traditional construction projects are associated with high rework costs that often exceed 10% of the total project cost (Davis, Ledbetter & Burati, 1989; Love, 2002), leading to unnecessary time and money wasted. In addition, rework, change orders, and project delays are caused by inadequate information quality and poor communication within organisations and amongst

different organisations working on a project (Georgiadou, 2019; Yap, Abdul-Rahman & Wang, 2016). Poor information exchange in construction projects is due to the competitive culture amongst project stakeholders and the nature of traditional construction contracts (Froise, 2014). These inefficiencies will most likely be improved by effective BIM implementation (Akintola *et al.*, 2017). If BIM is implemented effectively in a project, it promotes a more collaborative environment that enables more efficient information exchange amongst project stakeholders. Effective BIM implementation will lead to more reliable project information for better decision-making and higher project performance (Akintola *et al.*, 2017).

The declining growth of the SACI in terms of Construction Gross Fixed Capital Formation (CGFCF) and Construction Value Added (CVA) is shown in Figure 1, reflecting the trend of receding investments in buildings and civil works (Construction Industry Development Board, 2020). The construction industry hit a peak CVA of 16% in 2007 and gradually declined ever since (Figure 1). The Annual CIDB report for 2019/2020 stated that “*in both general building and civil engineering, business confidence is below 50%, reflecting an **industry in distress***” (Construction Industry Development Board, 2020).

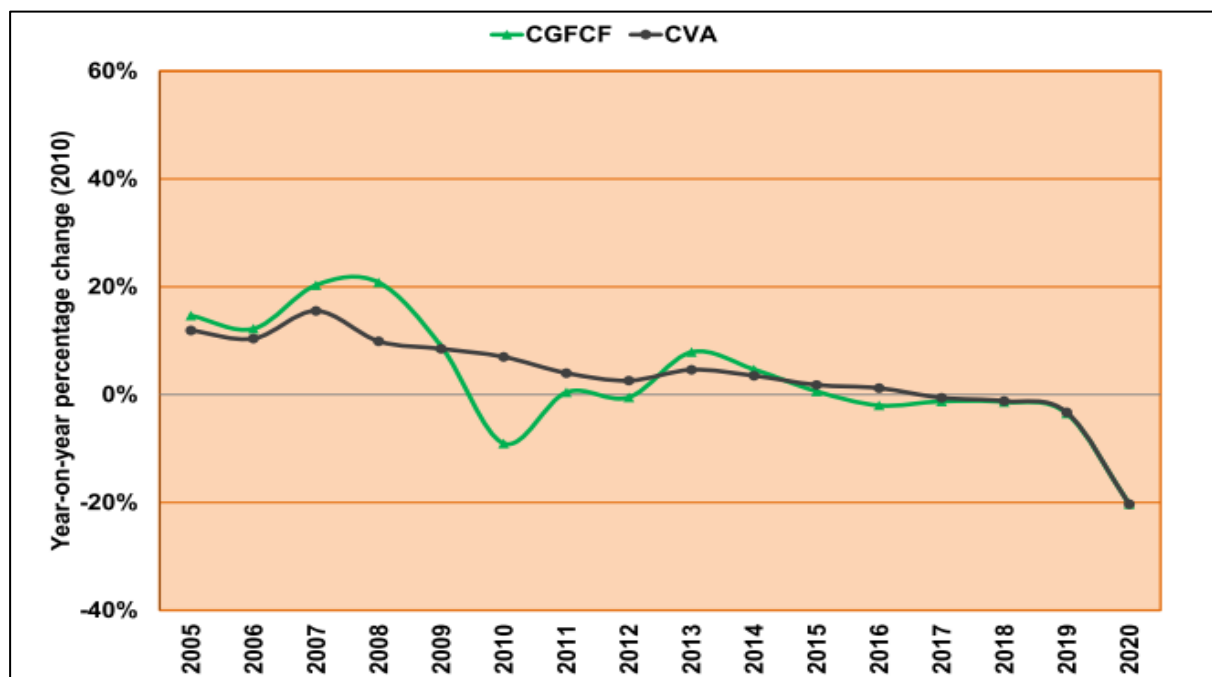


Figure 1: Declining growth of the SACI (Construction Industry Development Board, 2020)

Sibiya, Aigbavboa & Thwala (2015) mentioned that the SACI faces more serious and complex challenges than other countries. These challenges include poverty, skills shortages and corruption (Pillay & Mafini, 2017; Windapo & Cattell, 2013). In addition, the SACI is suffering from a decrease in client satisfaction and investments (Construction Industry Development

Board, 2020), which motivates the need to implement innovative processes such as BIM to increase the industry's performance. BIM implementation will foster economic benefits in terms of savings on project and operational costs. Furthermore, BIM promotes transparency in construction projects, which could mitigate the corruption issue commonly faced in South Africa (Meno, 2020). Furthermore, effective BIM projects are known to attract investors to a country (National BIM Council, 2017).

There is currently no research quantifying BIM uptake in South Africa relative to other countries. However, several studies have found that BIM uptake and BIM maturity is lower in South Africa compared to other countries (Akintola *et al.*, 2017; Govender, 2018; Meno, 2020; Mtya & Windapo, 2019). As a result, the competitiveness of the SACI is at a threat, and international companies are in an advantageous position to take work from local companies (Froise, 2014). Akintola *et al.* (2017) report that BIM has been present in the industry since 2010; however, its implementation has not been effective nor widespread because there is no structured approach or strategy at a national level to promote BIM adoption and implementation.

Numerous studies have identified the shortage of BIM implementation studies in developing countries (Bui, Merschbrock & Munkvold, 2016; Sahil, 2016; Saka & Chan, 2019), and more specifically, the importance of more research required for BIM implementation in South Africa (Chimhundu, 2015; Froise, 2014; Mtya, 2019). For example, Pillay *et al.* (2018) highlighted the need for further research into the challenges of BIM implementation and the cause of slow BIM uptake in South Africa. Chimhundu (2015) researched the barriers preventing BIM adoption in South Africa and recommended further research due to the continuously evolving challenges. Govender (2018) shared that more research is needed to promote BIM adoption in the industry.

Although many global strategies, programs, and initiatives can be applied to the South African industry, Meno (2020) noted that international strategies would not necessarily mitigate local challenges. Therefore, it is essential to analyse the risks associated with digitalisation in the SACI to ensure successful implementation (Meno, 2020). Furthermore, Papadonikolaki (2017) confirmed that BIM diffusion efforts applied from different countries would likely lead to misguidance, poor performance and poor satisfaction, which emphasises the need for specific research on BIM implementation strategies focusing on local South African challenges. Based on what previous researchers have identified, this study will focus on solutions to facilitate a smooth transition regarding BIM implementation across the SACI. Change is inevitable, but it can be appropriately managed if the required resources are in place to facilitate the process.

1.3 Aim and objectives

The SACI lacks widespread and effective BIM implementation. This research study aims to develop a proposal to facilitate BIM implementation across the SACI. The proposal could be used as a basis for further research on national BIM implementation strategies.

The objectives of this study are:

- i. Gain an understanding of the challenges associated with BIM implementation across the SACI.
- ii. Identify possible solutions in terms of initiatives and strategies to facilitate and promote BIM implementation across the SACI.
- iii. Identify the role-players responsible for facilitating BIM implementation across the SACI.
- iv. Provide practical guidance for South African organisations to implement BIM in terms of best practices.

1.4 Scope and limitations

There is an abundant amount of research focusing on the technical aspect of BIM implementation. However, there are still many problems and challenges preventing South African organisations from implementing BIM. Therefore, this study takes a holistic approach focusing on BIM implementation in the entire industry. Furthermore, the study is exploratory, meaning that the study seeks to understand BIM in the SACI better. The construction industry is also referred to as the AECO industry or the built environment, including buildings and civil works.

1.5 Research design

The seven chapters of the research investigation are shown in Table 1. In addition, the purpose of each chapter and the main deliverables are described. Thus, Table 1 provides the reader with an overview of the discussed topics in each chapter.

Table 1: Design of research investigation

Chapter	Purpose	Deliverables
1. Introduction	Gives the reader a clear understanding of the research problem and the desired outcomes of the research.	Background, problem statement and motivation, aim and objectives, scope and limitations, and research design.
2. Literature review	Provides the necessary theoretical information and explores existing research, focusing on the challenges and solutions for the SACI.	BIM theory, review of literature, challenges in SA, proposed strategies and initiatives in SA.
3. International BIM implementation	Explores global BIM implementation strategies and discusses the nature of the SACI.	Global BIM strategies, nature of SACI.
4. Methodology	Describes the nature of the research and the method of data capture and analysis.	Research approach, participant selection process and demographics, data collection, and data analysis.
5. Data analysis	Analyses the interview responses per interview question.	Participant demographics, interview response analysis.
6. Findings and discussion	Summarises the interview findings and compares the findings with the literature. Presents the final proposal.	Summary of interview findings and discussion for each objective. Final proposal.
7. Conclusion and recommendations	Concludes and provides recommendations for the industry and future research.	Conclusion and recommendations.

2 Literature review

This chapter aims to provide the reader with the necessary background information about BIM, explore existing research in the field, and provide information on which to base the research findings. Since this study builds on existing literature, a thorough review was conducted on the past research. The flow of the sections for Chapter 2 is shown in Figure 2. Starting with a broader overview of BIM in Section 2.1, the chapter narrows down to the focus area of the research regarding BIM solutions for the SACI in Section 2.4.

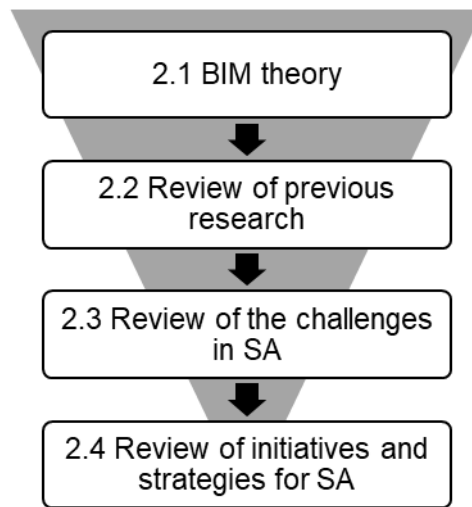


Figure 2: Diagram to show literature review sections (author)

First, the literature review starts with a broader theoretical background on BIM in Section 2.1 to give the reader an understanding of BIM. The definition of BIM is explained, and the value of BIM for different project stakeholders are described. After that, the concept of BIM maturity is clarified, and some information is shared on BIM standards and guidelines.

Section 2.2 provides a discussion and review of the past research on BIM implementation. This section starts by discussing some of the international studies and then discusses studies focusing on South Africa. In this section, the different research purposes and methodologies are discussed and compared with each other.

Section 2.3 focuses specifically on the challenges associated with BIM implementation in South Africa. This section aligns with the study's first objective. Before identifying the strategies, first, the challenges need to be understood. Therefore, this section forms a critical part of the research, and it forms a basis for the final research findings.

Finally, Section 2.4 focuses on the proposed strategies for BIM implementation in South Africa. This section aligns with the second research objective. The proposed strategies obtained from this section are compared against the interview findings during the discussions in Chapter 6.

2.1 BIM theory

This section provides the reader with theoretical background information about BIM since it is a complex phenomenon. First, the development of BIM is discussed, and the definition of BIM is given to explain what it means today. Then, the benefits of BIM are mentioned to justify why BIM implementation is essential and how different organisations and projects could benefit from it. An explanation of BIM maturity follows the benefits of BIM. Lastly, a short overview of BIM standards and guidelines is provided.

2.1.1 Development and definition BIM

Autodesk introduced BIM in 2002 to upgrade or improve 3D CAD (Bew & Richards, 2008). 3D CAD provided representations of buildings that were useful for visualisation purposes. However, there was a need for these models to contain more data that could be used to streamline and automate processes such as designing, calculating quantities and calculating costs (Bew & Richards, 2008). BIM models, in simple terms, are models that contain objects (walls, doors, windows, columns, etc.) with various properties (size, shape, colour, material, cost, etc.) assigned to each object (Gamayunova & Vatin, 2015). These objects and models contain geometric and non-geometric data. Some forms of data are related to quantities (3D), costing (4D), scheduling (5D) and facilities management (6D) (Cerovsek, 2011). Continuous technological advancements led to BIM models providing much more data than initially planned, such as sustainability data and health and safety data (Royal Institution of Chartered Surveyors, 2020). When Autodesk introduced BIM in 2002, the industry was not ready to adopt BIM yet. However, during the last decade, the value of BIM was realised, and BIM uptake increased exponentially (National Building Specification, 2020).

BIM started as a software tool to facilitate the design phase. However, the information contained in these models was discovered to be most valuable for the construction and operational phases of buildings and civil works. People make their decisions based on information, and good decisions can be made with good information. It was therefore realised that the value of BIM lies in the ability to manage information of built assets, to be able to make informed decisions about these assets. Thus, BIM evolved into more than a software tool and became an information management process (Royal Institution of Chartered Surveyors, 2020).

Hence the acronym is often referred to as “Building Information Management” because the “modelling” is now only a part of the process (Arayici, Egbu & Coates, 2012).

The BIM process includes collecting, managing and exchanging project information from a single source, called the Common Data Environment (CDE) (Royal Institution of Chartered Surveyors, 2017). CDEs play a critical role in successful BIM implementation since this is where project information is stored and shared. According to the ISO 19650 standard, a CDE is an “agreed source of information for any given project or asset, for collecting, managing and disseminating each information container through a managed process” (The British Standards Institution, 2019). It is also noted that “a CDE workflow describes the processes to be used, and a CDE solution can provide the technology to support those processes” (The British Standards Institution, 2019).

The latest international BIM standard, ISO 19650, defines BIM as the *“use of a shared digital representation of a built asset to facilitate design, construction and operation processes to form a reliable basis for decisions”* (The British Standards Institution, 2019). The ISO 19650 standard also states that these “built assets” referred to in the definition include buildings, roads, bridges and process plants, but are not limited only to these types of built assets (The British Standards Institution, 2019). The Royal Institution of Chartered Surveyors describes the definition of BIM as *“fluid”* and *“dynamic”*, and that *“it is driven by the creation and management of information during a project’s life cycle, supported by technology and a collaborative process”* (Royal Institution of Chartered Surveyors, 2020). The definition of BIM is often confusing, but the vital aspect to note is that BIM is not a technology but a process of information management.

2.1.2 Value of BIM

BIM is implemented in construction projects because of the benefits associated with its use throughout the entire built asset’s lifecycle (Ghaffarianhoseini, Tookey, Ghaffarianhoseini, *et al.*, 2017). Private and public asset owners worldwide have realised the benefits and asked for their projects to be delivered using BIM (McGraw Hill Construction, 2014b). However, the BIM process is collaborative, requiring buy-in from all project stakeholders in each project phase (design, construction and operations). Therefore, different stakeholders use BIM differently to execute their part of the project, and each stakeholder benefits from BIM differently. Therefore, it is helpful to know how different project stakeholders could apply BIM to see how they could benefit from BIM. Ismail (2019) outlined some of the main BIM uses for the different project stakeholders, as illustrated in Figure 3.

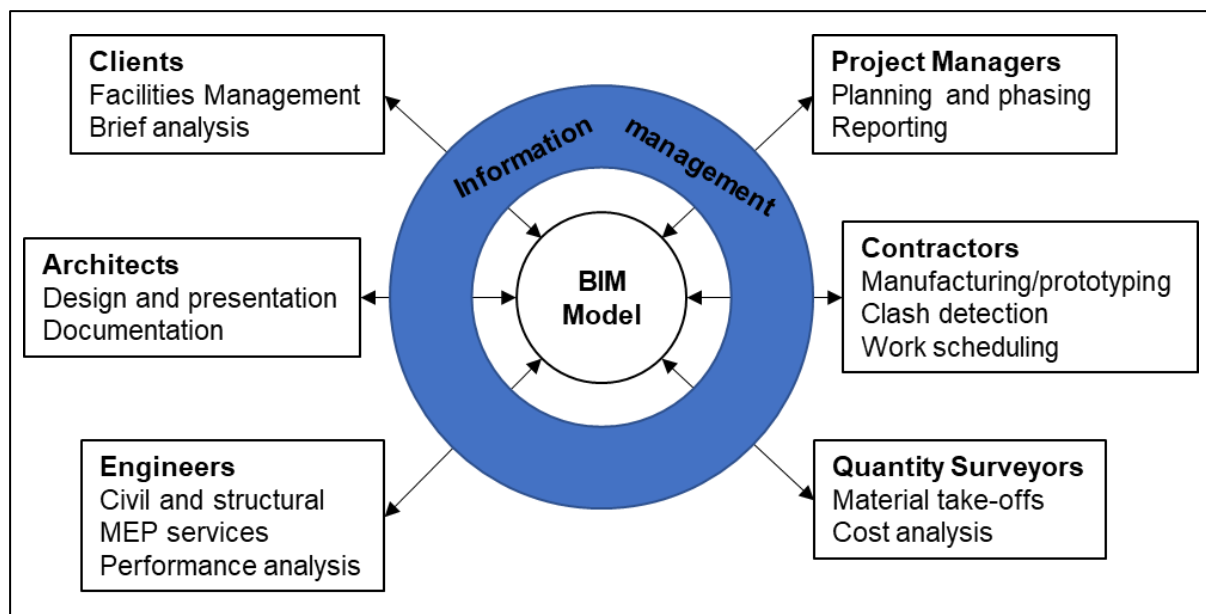


Figure 3: BIM uses for project stakeholders, adapted from Ismail (2019)

Benefits for designers:

Designers include engineers, architects and other consultants. They use authoring or modelling software to design in a 3D BIM environment, where data is mainly automatically generated and stored in a database (Froise, 2014). The data obtained from BIM models include quantities, costs, 2D drawings, product suppliers' details, etc. Therefore, much more information is being produced when designing BIM models, compared to using only 2D CAD (Smith & Tardif, 2009). In addition, BIM models can be analysed before the construction begins and can include structural, electrical, and mechanical analysis, automatic detection of design-related errors, clash-detection, performance analysis, code/standard validation, green rating analysis for sustainable practices, and Leadership in Energy and Environmental Design (LEED) certification (Lee, Oh, Kim, *et al.*, 2015; Son, Lee & Kim, 2015).

Some BIM applications include simulating crowd evacuation, crowd movement and crowd behaviour (Rüppel & Schatz, 2011). These BIM features enable better project planning, allowing informed changes to be made before construction starts, when changes still have a low impact on cost and time overruns (Smith & Tardif, 2009). For example, in a study from Stanford University, data was gathered on 32 major construction projects. The study found that BIM reduce changes in projects by 40% because of early detection of problems and reduces the time taken for cost estimates by 80% (Azhar, 2011).

Benefits for contractors:

Contractors could use the information generated by BIM models throughout the project, from the planning to the handover phase. There is no need for complex Excel sheets to calculate quantities because it is automatically calculated (Irizarry, Karan & Jalaei, 2013). Costs are also automatically calculated by applying fixed rates to construction components and materials (Irizarry *et al.*, 2013; Weisberg, 2008). The programme or schedule of the construction works can be simulated, phase by phase, by giving BIM objects time properties (Hay, 2016). The information obtained from BIM allows the contractor to understand the work better, allowing for better decision-making, site planning, work scheduling and identification of health and safety risks (Froise, 2014). Another benefit is that BIM models or objects can be provided to suppliers as a design for prefabricated elements (Ghaffarianhoseini *et al.*, 2017). Materials and construction components can be ordered online and delivered on a predetermined day to reduce waste and minimise stockpiling (Poirier, Staub-French & Forgues, 2015). The contractor can also use BIM for clash detection, project coordination and constructability analysis (Azhar, Khalfan & Maqsood, 2012).

BIM is being used onsite through mobile or handheld devices such as tablets, which was proven to be another significant benefit (Davies & Harty, 2013). BIM models can be accessed on-site, viewed in 3D, and all project details can be obtained from them (Davies & Harty, 2013). Not only does this give the workers accurate information about project quantities, schedules, or locations, but it gives them a better understanding of the overall project, and it increases their productivity (Poirier *et al.*, 2015). In addition, this enables construction workers to visualise the project and see how the works need to be carried out, allowing for better construction safety management and early identification of hazards (Ganah & John, 2015; Hong, Jung, Kim, *et al.*, 2015).

Clients and all project stakeholders can be granted access to specific project information using CDEs, and this reduces duplication of information and unnecessary requests between stakeholders such as RFIs (Ghaffarianhoseini *et al.*, 2017). In addition, clients could now better understand the project since they have instant access to the project information through a cloud-based platform (Sahil, 2016). Furthermore, BIM models keep the client excited and engaged in the project, strengthening contractor-client relationships and maintaining clients for future projects (McGraw Hill Construction, 2012).

Benefits for asset owners:

The asset owner could obtain the most value from BIM since it reduces cost and time overruns (McGraw Hill Construction, 2014b). An as-built BIM model could be provided to the client at the end of the project, containing information about the asset to assist the operational phase (Hong *et al.*, 2015). The information provided by as-built models could include routine maintenance of heating systems, building management systems, building fabric, mechanical, electrical and civil works, maintenance data, evacuation plans and fire detection systems (Georgiadou, 2019). This information can be used to reduce facility management costs, perform preventative maintenance, and allow for easier future renovations (Cheng & Ma, 2013; Kassem, Kelly, Dawood, et al., 2015; Zou).

Benefits of BIM for the project:

Effective BIM implementation contributes to an integrated project delivery (IPD) approach (Froise, 2014). The American Institute of Architects (AIA) California Council (2007) defines IPD as a *“project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction”*. The focus of an integrated project delivery approach is on project collaboration. Effective collaboration promotes quick and reliable exchange of project information, which leads to better project performance.

Figure 4 illustrates how increased collaboration and better information exchange amongst project stakeholders lead to a more integrated project delivery system. The concept of IPD encourages project stakeholders to work together for the benefit of the project instead of working in their silos for their own benefit. BIM implementation is a process that helps to work toward IPD.

Another significant advantage of a BIM project is that a greater design effort is applied earlier on in the project than traditional construction projects, illustrated in Figure 5 (Smith & Tardif, 2009). In addition, BIM allows for the integration of multidisciplinary design fields from early on in the project, which reduces errors, design clashes and constructability issues and therefore reduces the amount of rework on a project (Ghaffarianhoseini *et al.*, 2017; Hwang, Zhao & Yang, 2019). Although the IPD process involves a similar design effort, this effort is shifted to an earlier stage (see the design effort shift in Figure 5). Putting in more effort at the start of the

project enables important decisions to be made before construction commences and therefore reduces change orders later on in the project, which will have a much more significant impact on the project cost (McGraw Hill Construction, 2014b).

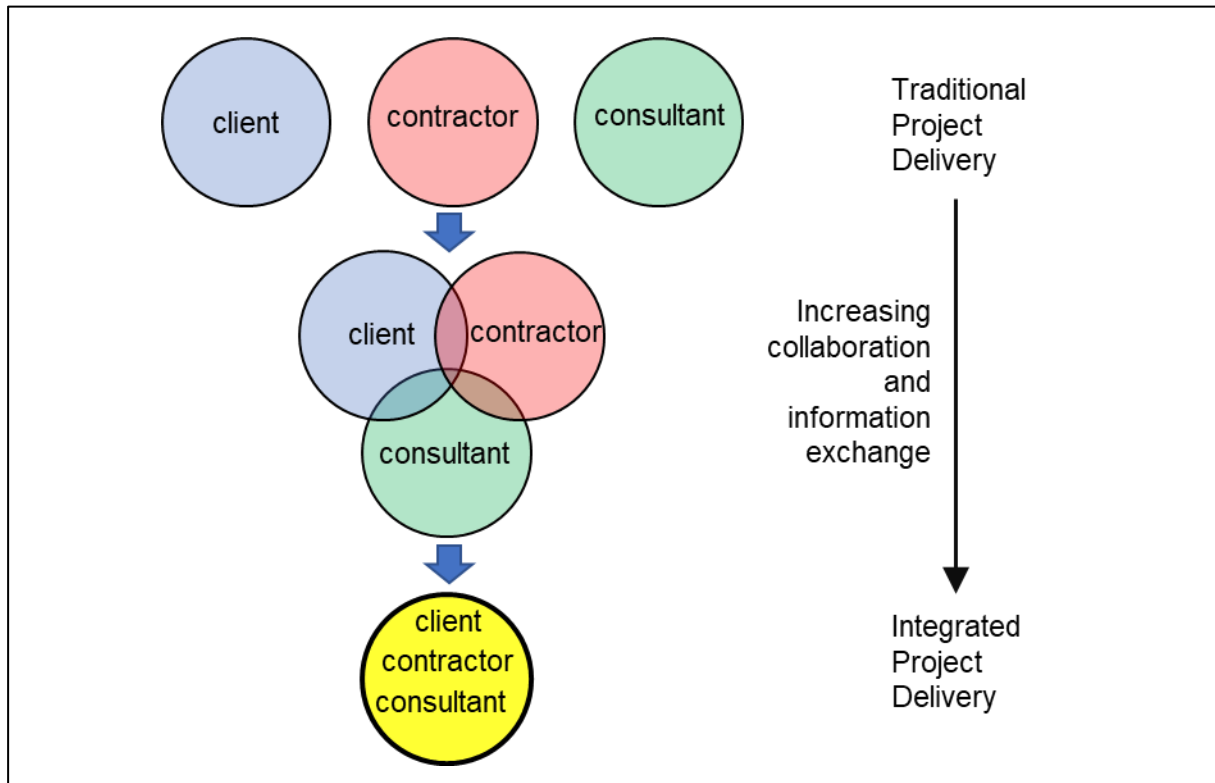


Figure 4: Illustrating a more collaborative and integrated approach to project delivery (author).

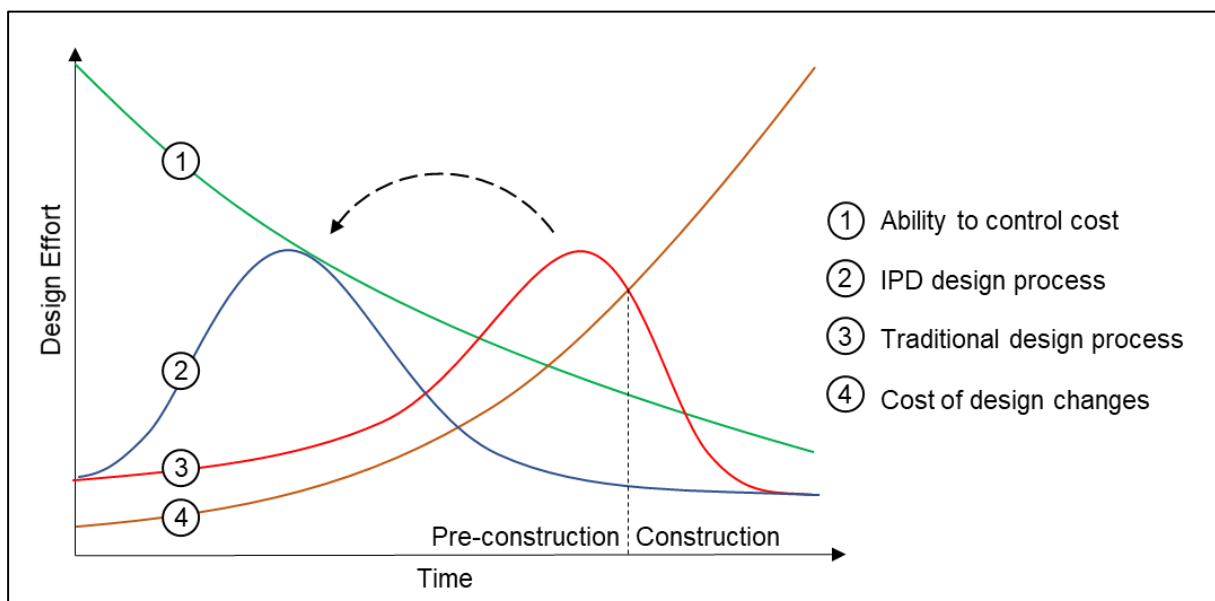


Figure 5: Traditional versus IPD design process, adapted from Smith & Tardif (2009)

2.1.3 BIM maturity

The definition of BIM is “fluid” and “dynamic” (Royal Institution of Chartered Surveyors, 2020), and the application of BIM can vary, depending on the project type, the project size, and the desired BIM outcomes. Therefore, BIM implementation should be measured to establish the quality and quantity of information obtained from BIM and its benefit to the project. The most suitable measurement of BIM implementation was previously described as ‘BIM maturity’ (Edirisinghe & London, 2015). However, this measurement is now described as ‘information management’ (Royal Institution of Chartered Surveyors, 2020). Hence, this section will explain the evolution of ‘BIM maturity’ over the past decade from when it was defined by Bew and Richards in 2008 until today as the ISO 19650 standard define it.

Bew and Richards (2008) created a BIM maturity diagram to differentiate four levels of BIM maturity. These four levels of BIM maturity can be summarised as:

- Level 0: Applying traditional 2D CAD or no BIM.
- Level 1: Applying 2D and 3D BIM models primarily for design and using a collaborative CDE environment. Project data such as quantities, costs and schedules are not integrated but managed separately. The BS:1192:2007 standard describes information management according to Level 1.
- Level 2: This entails federated information models, which are made up of different models from various disciplines (architecture, structural, electrical, etc.). Programme (4D), cost (5D) and facilities management data (6D) can be extracted from the models. The ISO 19650 standard describes information management according to Level 2.
- Level 3: All project lifecycle stages are modelled through integrating various disciplines and working collaboratively. The international standard describing BIM level 3 is still under development.

In 2009, Bilal Succar, from the University of Newcastle, Australia, studied international BIM frameworks and divided the different stages of BIM implementation in the following manner:

- Pre-BIM: Traditional processes using 2D or 3D CAD.
- Stage 1: Modelling of objects using BIM software.
- Stage 2: Collaboration stage, which involves the collaboration of different model disciplines.
- Stage 3: Network-based integration, which involves the integration of different models across different project lifecycles.

- IPD: Most mature BIM implementation, optimising and streamlining project processes and utilising BIM features such as costing, scheduling, sustainability, and facilities management.

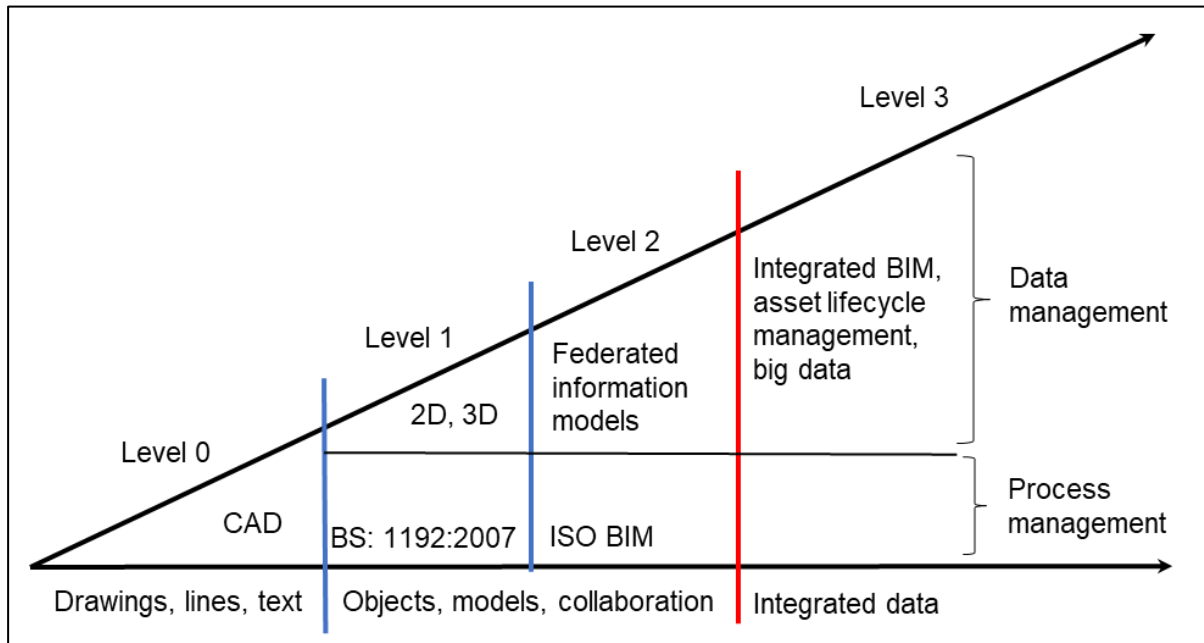


Figure 6: BIM maturity diagram, adapted from Bew & Richards (2008)

BIM maturity, as defined by Bew & Richards (2008) and Succar (2009), was quite similar. Both described BIM maturity as having four or five levels or stages, starting at traditional processes and the most mature stage being an integrated project delivery system. In the latest BIM standard, ISO 19650, BIM maturity is categorised into only three stages, which builds on the explanation of Bew & Richards (2008) and Succar (2009). The ISO 19650 standard, however, recognises that BIM maturity can not only be defined by technology use and that the technology is only part of BIM. Therefore, each stage is defined by four layers of focus areas that improve with increasing BIM maturity, as seen in Figure 7.

The four layers are described more clearly below (The British Standards Institution, 2019):

- **Standards layer:** the processes and policies followed to ensure that project information (documents, models, federated models, schedules, quantities, etc.) are collected, managed, and exchanged securely during the entire project lifecycle. This layer includes standards such as ISO 19650-1 and ISO 19650-2.
- **Technology layer:** capable hardware and software, based on a CDE platform where project stakeholders store and access all project data. This could be a combination of multiple technologies that can store and manage information.

- Information layer: useful information that is produced from the data that was captured and analysed by technologies.
- Business layer: the benefit gained from the standards, technology, and information layers. These benefits may include operational effectiveness or strategic competitiveness.

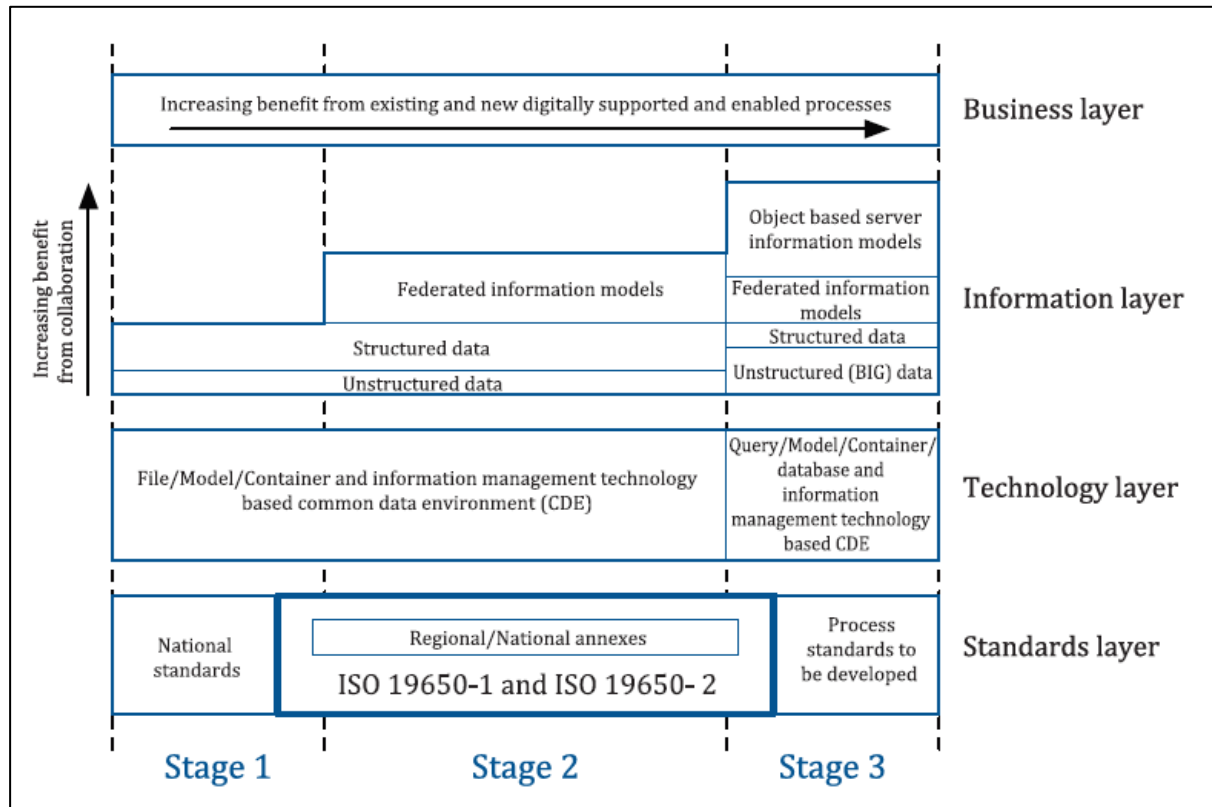


Figure 7: Stages of maturity according to ISO 19650 (The British Standards Institution, 2019)

The measurement of BIM maturity shifted from a measurement of the application of technology to a measurement of information management that includes layers such as standards, technology, information and business. A significant addition to the ISO 19650 standard is the inclusion of the business layer. This layer means that BIM standards, BIM technologies, and BIM information should align with business goals to benefit the business. Thus, an increasing BIM maturity should increase the benefits to the business in terms of operational or strategic competitiveness.

2.1.4 BIM standards and guidelines

Various organisations around the world have developed national standards and policies to guide companies on how to effectively implement BIM (Glema, 2013). These organisations

include Natspec (Australia), Building and Construction Authority (Singapore), General Service Administration (USA), American Institute of Architects (AIA, USA), Senate Properties (Finland) and the British Standards Institute (UK). Many of these organisations and countries produced their own guidelines, standards and protocols to guide BIM implementation. For example, New Zealand released a national BIM handbook that explains what BIM means to the country and clarifies BIM processes during a built asset's design, construction, and operational phases (BIM Acceleration Committee, 2019). The USA released BIM execution planning documents to guide users using BIM (BIM Acceleration Committee, 2019). The AIA in the USA released BIM protocols that set out required BIM deliverables in a project. Singapore's Building and Construction Authority have released several guides to assist organisations with implementing BIM (Building and Construction Authority, 2018). These national strategies and initiatives are discussed in more detail in Chapter 6.

A standard or guideline used in one country cannot automatically be used in another country due to varying levels of maturity and legislation differences (Howard & Björk, 2008; Succar, 2009). However, if every country or organisation implements BIM differently and has a different perception or standard of BIM, it creates confusion, especially on multi-national projects. Therefore, the ISO 19650 standard was developed, which is regarded as an international standard because it has been accepted as the European standard and is bound to be used by 34 European countries (The British Standards Institution, 2019). Many years of research and practice have led to the development of the ISO 19650 standard, making it very useful for communicating about BIM. However, it still does not address country-specific aspects that might be important for BIM implementation. Therefore, many countries have adopted the ISO 19650 standard and included a national annex to address country-specific policies.

2.2 Review of previous literature on BIM implementation

An abundant amount of existing research focused on BIM implementation at organisational, project, and industry levels. Although this study focuses primarily on BIM implementation at an industry level, BIM implementation is seen as a system where these three levels overlap and have interlinking relationships. Hence, the technical or practical aspects of organisational and project BIM implementation are essential for approaching BIM implementation at an industry level. This section covers selected past studies that were regarded as necessary for this study. These may have similar research objectives, similar research methodologies, or they may only have valuable findings concerning BIM implementation. The literature is discussed in chronological order and compared to each other.

2.2.1 Global research

A popular study in the field of BIM was the development of the BIM framework by Succar (2009). Succar explored 14 BIM guidelines, identified and visually expressed certain BIM concepts, and developed a BIM framework. The framework expressed educational and industry deliverables to support BIM implementation at an organisational, project and industry level. Succar's (2009) diagram expressed three required fields for effective BIM implementation: policy, process, and technology. The diagram is illustrated in Figure 8. There is often a misconception that BIM is only a technology and that only software providers facilitate or drive BIM. In contrast, Figure 8 shows the resources needed to implement BIM (such as standards, regulations, and software) and the industry entities responsible for providing these resources (such as research centres, regulatory bodies, and software vendors). Succar's (2009) diagram shows that BIM implementation requires a collective effort from different industry role-players, and could be valuable for developing a national BIM implementation strategy for South Africa.

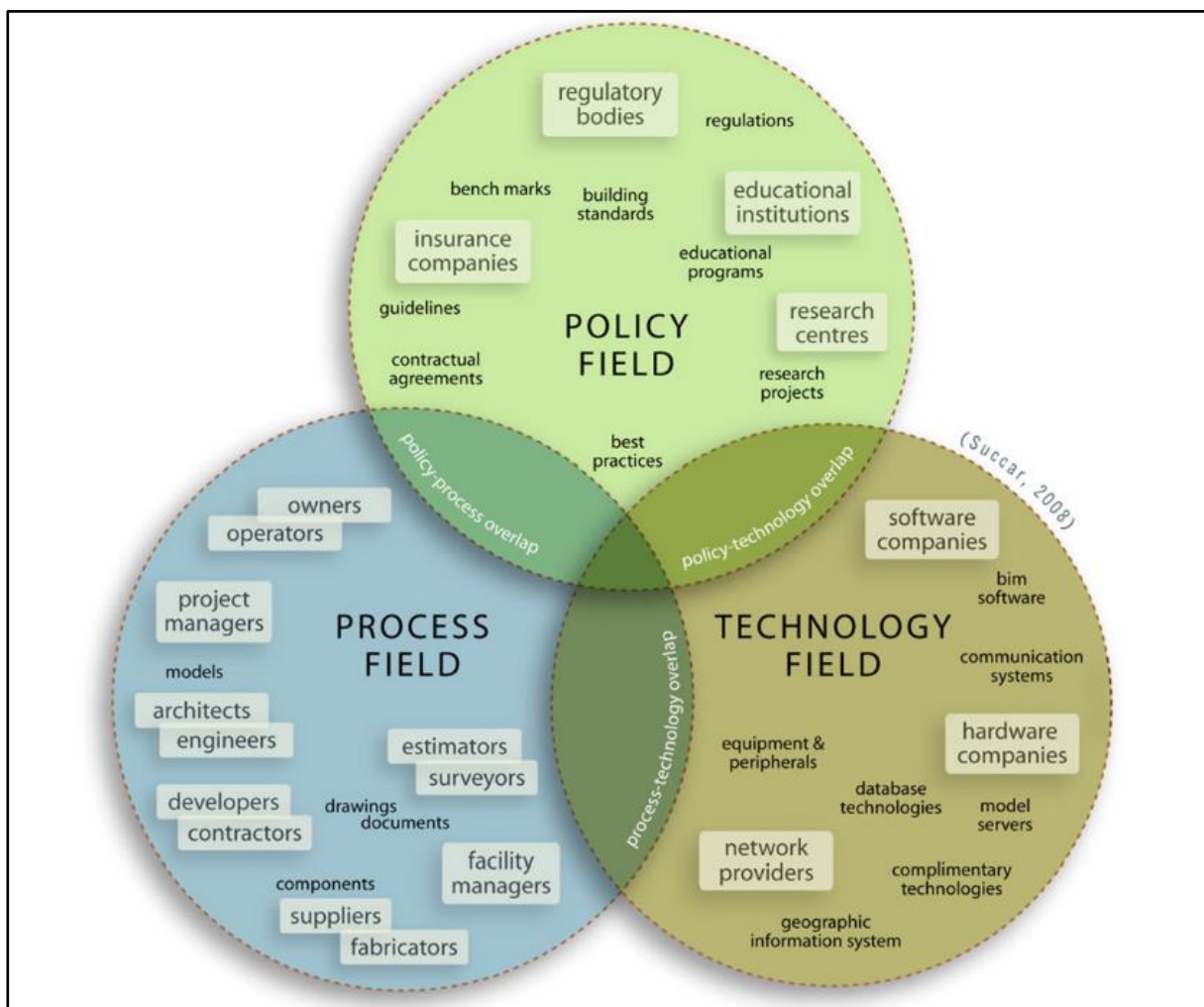


Figure 8: Succar's (2009) three interlocking fields of BIM activity

A few years after Succar's (2009) study, Khosrowshahi & Arayici (2012) released a study that developed a roadmap for BIM implementation in the UK construction industry. Their research entailed (1) establishing BIM maturity through a literature review, (2) conducting interviews with large organisations in Finland to obtain best BIM practices and (3) conducting surveys with contractors in the UK construction industry. By analysing the data obtained from literature, interviews and surveys, they found three main fields to address BIM implementation, similarly to Succar (2009). The three fields that need to be addressed to implement BIM were education and training, organisational culture, and information management (Khosrowshahi & Arayici, 2012). The result was the development of a roadmap to express the issues experienced by organisations in implementing BIM visually. By identifying the organisational issues on BIM implementation, Succar (2009) contributed to developing BIM guidance and strategies for the broader picture of accelerating BIM implementation in the UK. The current study takes a similar approach to Khosrowshahi & Arayici's (2012) research but with more focus on the solutions relevant to the South African industry today.

Sun, Jiang, Skibniewski, *et al.* (2015) conducted a study on the limiting factors to BIM implementation and provided some recommendations to overcome them. Five main limiting factors were identified and labelled as technology, cost, management, personnel, and legal. Sun *et al.* (2015) made valuable suggestions to mitigate these limiting factors. However, Sun *et al.* (2015) had one shortcoming in their study; they only had one source of information, which was literature, unlike Khosrowshahi & Arayici (2012) that used literature interviews and surveys. BIM implementation is practised by the people in the industry, which justifies the need to gather information from the industry in the form of interviews, surveys or questionnaires.

Sahil (2016) conducted a phenomenological study on how to facilitate BIM adoption in developing countries. The research entailed conducting interviews with a focus group of six professionals that have a good knowledge of BIM and practical BIM experience. The nature and purpose of Sahil's (2016) research are very similar to the current study, except that it focused on BIM implementation at an organisational level and not on an industry level. Furthermore, in Sahil's (2016) study, only one of the interviewees were from a developing country, and most of them worked for contracting firms, making the study very specific. However, Sahil's research approach and some of their findings generated valuable ideas. Sahil (2016) concluded with the main lessons learned according to the following categories: educational requirements, infrastructure requirements, sound practices and working with organisations with no BIM experience.

Kouch (2018) developed a simple framework for Small and Medium Enterprise (SME) contractors to implement BIM in their organisation. Similarly to Sahil (2016), Kouch (2018) produced valuable findings that could assist BIM implementation at an organisational level. However, both these studies are not focused on an industry level of BIM implementation. Nevertheless, the framework developed by Kouch (2018) is still useful since it simplifies BIM implementation in three phases, as shown in Figure 9. One of Kouch's (2018) shortcomings, similar to Sun *et al.* (2015), was that they failed to collect data from people in the industry through interviews, surveys or questionnaires.

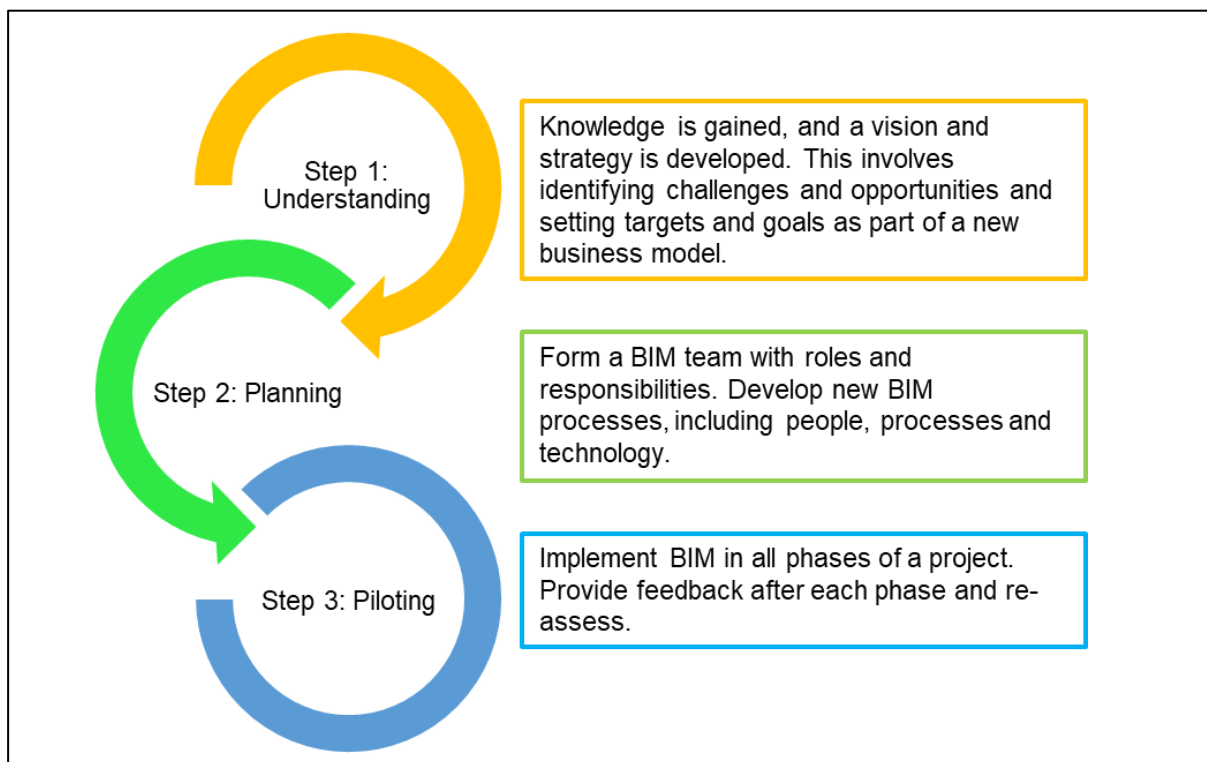


Figure 9: Three BIM implementation steps, adapted from Kouch (2018)

A study focusing on BIM implementation in UK residential projects was conducted by Georgiadou (2019). Georgiadou (2019) found that there is no single method or solution for BIM implementation at a project level, because all projects are different. Therefore, it will help to have a collection of case studies with best practices for different BIM projects around the world. Georgiadou (2019) also stated that BIM implementation at an organisation involves a change in procurement models and business models, and that the long-term benefits of successful BIM implementation should be considered. At an industry level, Georgiadou (2019) recommended that initiatives need to be developed to assist SMEs with BIM implementation and that educational programmes should be launched in the built environment to teach students collaborative BIM work practices. Georgiadou (2019) used cross-comparison by

analysing data from literature and semi-structured interviews, to justify their findings. Similar to Khosrowshahi & Arayici (2012) and Sahil (2016), Georgiadou's (2019) data were not only collected from literature, but people's perspectives were considered.

A study by Vidalakis, Abanda & Oti (2020) investigated the adoption and implementation of BIM in SME's, which is similar to Kouch (2018). However, their research methodology involved a focus group approach to help set up a questionnaire survey, which was then distributed to the industry. Similar to Khosrowshahi & Arayici (2012), Sahil (2016), and Georgiadou (2019), they made use of people's perceptions to obtain their findings. Vidalakis *et al.* (2020) found that the largest barrier to BIM adoption in SME's is the costs associated with BIM implementation. This barrier was countered by Sun *et al.* (2015), who stated that cost should not be a barrier because the long-term benefits will exceed the initial implementation costs. Vidalakis *et al.* (2020) concluded that the full benefits of BIM could only be realised if there is buy-in from all project stakeholders in the supply chain. Vidalakis *et al.* (2020) found that further adoption should be facilitated through (1) effective leadership, (2) industry initiatives and (3) peer education. Although the focus was on BIM implementation at an organisational level, these solutions can also be considered at an industry level.

In a recent study on BIM adoption, conducted by Brito, Ferreira & Costa (2021), the focus was on BIM adoption for public organisations in Brazil. The research approach and design could be useful for the South African context since Brazil is also a developing country with a low BIM maturity level (Brito *et al.*, 2021). The research focused on public organisations because of their important role in driving BIM in the industry. Brito *et al.* (2021) identified 16 critical success factors (CSF) for BIM adoption, which were prioritised into only 10 CSFs. These CSFs were sorted according to the same BIM implementation fields identified by Succar (2009), namely technology, process, and policy. In addition, each CSF was sorted according to the different dimensions of analysis, namely, organisation, project and industry. Although the focus of the research by Brito *et al.* (2021) was on public organisations in Brazil, a similar research method could be applied to the South African industry.

From the international research discussed above, Table 2 was developed to summarise the notable findings of these studies. Throughout the research, these findings are considered background information and serve as a basis for the development of the current study's methodology and research findings.

Table 2: Summary of notable findings from international research

<p>Succar (2009):</p> <p>BIM implementation requires three overlapping fields, including policy, technology and process. Many companies drive, facilitate or promote these fields, including software companies, hardware companies, research centres and regulatory bodies.</p>
<p>Khosrowshahi & Arayici (2012):</p> <p>The three fields that need to be addressed in BIM implementation are:</p> <ul style="list-style-type: none"> • education and training, • organisational culture, and • information management.
<p>Sun et al. (2015):</p> <p>The five main limiting factors to BIM implementation were related to:</p> <ul style="list-style-type: none"> • technology, • cost, • management, • personnel, and • legal.
<p>(Sahil, 2016):</p> <p>The main lessons learned from this study were grouped according to the following categories:</p> <ul style="list-style-type: none"> • educational requirements, • infrastructure requirements, • sound practices and • working with organisations with no BIM experience.
<p>(Kouch, 2018):</p> <p>SME contractors should implement BIM using the following main steps:</p> <ol style="list-style-type: none"> 1. Understanding (Discover BIM implementation strategy, vision and business goals) 2. Planning (Form a BIM team, restructure the firm, assign BIM roles and responsibilities) 3. Piloting (Implement BIM in a project)
<p>(Georgiadou, 2019):</p> <ul style="list-style-type: none"> • There is no single solution to implement BIM that works for everyone. Well documented case studies will, however, be valuable for implementing BIM. • Firms should consider the long-term benefits of BIM.

(Vidalakis *et al.*, 2020):

- The full benefits of BIM can only be gained if there is buy-in from all project stakeholders.
- BIM adoption should be facilitated through (1) effective leadership, (2) industry initiatives and (3) peer education.

(Brito *et al.*, 2021):

BIM implementation should be considered according to the different levels or dimensions of analysis, namely, organisation, project and industry.

2.2.2 South African research

Although the research on BIM adoption in South Africa is limited, the existing studies were reviewed to form a foundation for this study. The BIM implementation challenges and proposed strategies for South Africa are discussed in greater depth in sections 2.3 and 2.4 respectively. However, this section will cover the research focus and approaches of these studies.

Froise (2014) and Kiprotich's (2014) studies were among the first South African BIM studies. Froise (2014) focused on using BIM as a catalyst for an IPD culture in South Africa. They conducted their study by developing a survey based on a case study, and sent the survey to industry representatives. Kiprotich (2014) focused on BIM application for project management and collected their data through questionnaires and interviews. The findings of Kiprotich (2014) are justified more than the findings of Froise (2014) since it is based not only on a single case study followed by quantitative data but also on many perceptions and quantitative data from the interviews. Another study that provided valuable information was conducted by Chimhundu (2015). Chimhundu's (2015) study was exploratory, and due to the limited available research on BIM implementation, they used a quantitative research methodology by conducting surveys. Their use of surveys is similar to the study conducted by Froise (2014).

Akintola *et al.* (2017) focused on the critical constraints to widespread and optimal BIM implementation in the SACI. Their data was collected through semi-structured interviews with selected consultants who have implemented BIM, similar to the Sahil (2016) and Georgiadou (2019) studies. The shortcomings of their research were that the interviews were not conducted with all project stakeholders, such as asset owners, contractors and engineers. In addition, the focus was more on the problems (challenges) rather than solutions (strategies). In contrast with Akintola *et al.* (2017), Govender (2018) obtained data from a diverse range of construction industry stakeholders, including construction managers, engineers, quantity

surveyors and architects. Govender (2018) focused on BIM and IPD awareness in South Africa. However, Govender's (2018) research was quantitative, and their findings were not explicitly based on expert opinions.

The most recent studies on BIM implementation in South Africa are those of Mtya (2019) and Meno (2020). Mtya (2019) focused on measures for BIM adoption, capability and maturity in construction and consulting firms in South Africa. Mtya's (2019) research was quantitative and qualitative since questionnaires and interviews formed part of their data collection. Mtya (2019) found that BIM maturity and awareness are still relatively low in South Africa. Meno (2020) focused on the risks associated with digitalisation in the construction industry, which entails BIM implementation. The research data of Meno (2020) was primarily collected through questionnaires. Although there was a lack of expert opinions regarding BIM implementation in South Africa, Meno's (2020) study provides general insight regarding the change in the construction industry.

The global and South African research is used as a basis to develop the research methodology and it is compared to the study's findings in Chapter 6. More information about BIM implementation in South Africa is shared in sections 2.3 and 2.4.

2.3 Review of the challenges to BIM implementation in South Africa

In this section, the South African research is thoroughly discussed in terms of BIM implementation challenges faced by the industry. The existing research allowed the researcher to identify common themes of BIM implementation challenges in South Africa. The past research is compared with each other and discussed according to these identified themes:

- Lack of BIM competency in industry and education
- Lack of BIM research and awareness
- Lack of industry guidance and leadership for BIM implementation
- High implementation costs and uncertainty in returns
- Lack of a legal framework
- Cultural and social barriers
- Lack of government support
- Lack of support and drive from all project stakeholders and industry institutions
- Ineffective traditional procurement system

2.3.1 Lack of BIM competency in industry and education

Several studies have revealed that the lack of knowledge and education in BIM is the most significant barrier to BIM implementation in South Africa (Chimhundu, 2015; Kekana, Aigbavboa & Thwala, 2015; Moodley, Mathye & Radebe, 2016). Moodley *et al.* (2016) confirmed this when they found that South African Architecture Engineering and Construction (AEC) industry professionals lack the necessary skills to implement BIM in a mature, effective manner. Hence employees need to be sent on expensive and tedious BIM training courses.

Pillay, Musonda & Makabate (2018) confirms the lack of BIM in South Africa's education in their study when they researched 9 out of 13 universities in South Africa that offered research in the built environment. They concluded that the implementation of BIM at these institutions is extremely low. It was found that the industry lacks knowledge and understanding of the basics concepts of BIM, the philosophy of BIM and the basic BIM processes (Pillay *et al.*, 2018). The lack of awareness of BIM in South Africa raises concerns, according to Mtya (2019). Many AEC organizations that have digitalized are now requiring digital skills as an employee requisite (Meno, 2020). Moodley *et al.* (2016) emphasize that graduates will be disadvantaged if they are not digitally competent since it is one of the required skills in today's construction industry.

Pillay *et al.* (2018) state that one of the reasons for BIM not being taught at educational institutions is that the lecturers themselves lack BIM knowledge. Since BIM is still a relatively new concept, it cannot be expected that lecturers have practical BIM experience. Therefore, the lack of BIM knowledge is explainable. Furthermore, although the academics may not have practical experience, the industry lacks mature BIM implementation. Therefore, it is difficult to find experienced facilitators in South Africa (Tabesh, 2015). Moodley *et al.* (2016) state that another reason for the lack of BIM education is that it is difficult to fit it into the already full curriculum and increase the students' workload.

2.3.2 Lack of BIM research and awareness

In a study conducted on South Africa's AEC industry, Chimhundu (2015) found that architects and engineers are the primary BIM users in South Africa. Similarly, Kekana *et al.* (2015) confirm that BIM is mainly used by designers (architects and engineers), but add that BIM is also used by management. In a study conducted by Froise (2014), it was found that 12% of the contractors in SA use BIM, compared to 74% of contractors in the USA who have adopted BIM. A more recent survey conducted on large and small contractors and consultants in South

Africa showed that 94% of the respondents have some form of BIM capability. However, only 19% of the respondents had a level of BIM maturity (Mtya, 2019). These findings show a gradual uptake in BIM over the past years, but the low level of maturity, especially amongst contracting firms, raises concerns.

Kiprotich (2014) concluded that there is a lack of BIM experts in the SACI. The main factors preventing BIM implementation and partnering in the SACI are a lack of awareness by clients, contractors and industry bodies, and a fragmented procurement process (Froise, 2014; Govender, 2018). Succar (2009) states that a lack of understanding and awareness of BIM is due to a general lack of research in the field, the scope of BIM research and the confusion associated with broad and unclear definitions related to BIM capabilities. South Africa is currently spending far less money on research and development in modern technology trends and innovation in the built environment compared to other countries (Meno, 2020). Meno (2020) states that developers and stakeholders are reluctant to invest in innovative technologies due to the insubstantial research and development in the construction sector.

2.3.3 Lack of industry guidance and leadership for BIM implementation

A lack of national BIM standards inhibits effective coordination, communication, collaboration and partnering, and inhibits BIM adoption in general (Al-Shammari, 2014; Beach, Rana, Rezgui, *et al.*, 2015; Shibeika & Harty, 2015). Standards are meant to coordinate information production and exchange throughout the design, construction, and operational phases of a built asset's life (The British Standards Institution, 2019). Unfortunately, South Africa still has no countrywide accepted standards or guidelines for BIM implementation (Akintola *et al.*, 2020).

The SA BIM institute drafted BIM protocols for South Africa, however, it was almost a duplication of the UK BIM standards and guidelines, and it did not achieve industry consensus (Akintola *et al.*, 2017; Wortmann, Root & Venkatachalam, 2016). As a result of an absent BIM standard agreed upon by the industry, some organizations in South Africa have adopted their own standards and guidelines from BIM-mature countries around the world and made adjustments to suit the local context (Akintola *et al.*, 2017). Unfortunately, this has led to fragmented patterns of BIM adoption and varying maturities amongst South African AECO firms (Akintola *et al.*, 2017).

2.3.4 High implementation costs and uncertainty in returns

Optimal BIM implementation requires substantial costs involving software licenses, hardware upgrades, training costs and overall change management costs. The initial investment in implementing BIM is a significant barrier preventing widespread adoption across the SACI (Chimhundu, 2015; Meno, 2020), especially in smaller businesses (Kiprotich, 2014), where the returns are small compared to the cost of software licenses and upskilling staff. In addition, the digitalization process is not a once-off investment; it is a continuous process that evolves with technological advancements and will therefore always be viewed as complex and expensive (Meno, 2020). The training costs are perceived to be the largest expense in BIM implementation (Becerik-Gerber & Kensek, 2010; Elmualim & Gilder, 2014), especially in South Africa, where there is a lack of proficiency in BIM and digital capabilities. Another reason for low BIM adoption rates in South Africa is the cheap labour rates that are more attractive than expensive technological investments (le Roux, 2018). These costs are preventing many organizations, especially contractors, from even considering adopting BIM.

Although the global construction industry has recognized the value of BIM, there is still a lack of hard evidence or references for a substantial return on investments to justify the implementation costs (Chimhundu, 2015; Frits, 2007; Muro, Liu, Whiton, *et al.*, 2017). It is generally difficult to quantify the benefits of BIM due to the many factors that need to be considered, such as different construction project types, different technologies used, different processes applied and different companies that use BIM. What makes it particularly difficult in the South African industry is the lack of evidence of effective BIM implemented projects, which is a concern and prevents many company owners in South Africa from adopting BIM.

2.3.5 Lack of a legal framework

A major challenge preventing optimal and collaborative BIM implementation is the legal concerns such as ownership of data, intellectual property rights and design liability (Gu & London, 2010). For example, during the design phase where multidisciplinary teams should optimally work together on a single platform, there is a concern regarding the ownership of the design (Azhar, 2011; Mason, 2017), which may lead to copyright and liability issues in the case of a design failure (Meno, 2020). Another concern about sharing information and working on collaborative platforms is the confidentiality of tender rates and private company information (Meno, 2020).

Froise (2014) administered a survey to AEC stakeholders in South Africa and found that one of the main factors that inhibit collaboration is a lack of contractual boundaries. Chimhundu (2015) similarly identified the lack of a legal framework for BIM projects. Furthermore, there is no government- or industry-driven standard to guide BIM implementation. As a result, BIM is implemented differently in small pockets in the industry with their own protocols or addendum clauses to address the legal challenges (Akintola *et al.*, 2017). Successful BIM implementation requires a collaborative approach during the design and construction phases, and the current legal and contractual barriers prevent this from happening.

2.3.6 Cultural and social barriers

Henderson & Ruikar (2010) found that past research has shown that technology adoption is not slowed down by the technology itself but by the people who will use it and their attitude towards it (Henderson & Ruikar, 2010). Digitalisation is a process of change management that requires technology-human integration, therefore, the mental, emotional and behavioural challenges related to people should be considered constantly (Henderson & Ruikar, 2010; Rezgui & Zarli, 2006). People regard digitalization as a risk because it is different from traditional processes that used to work for years (Hwang, Trupp & Liu, 2004; Vass & Gustavsson, 2017). Digitalisation is rejected by many, especially older people who have grown accustomed to traditional ways of doing things, and they see that new technology only disrupts these processes (Alaghbandrad, Nobakht, Hosseinalipour, *et al.*, 2011; Hlahla, 2013). Some employees do not see the value of digitalization, and they believe it will only cause a disruption (Meno, 2020). Others see digitalization as a threat to their jobs (Hlahla, 2013) since the very reason for technology adoption is to streamline processes, which means some tasks and skills would not be required anymore (Meno, 2020). In South Africa, there is a fear that digitalization would reduce employment opportunities (Meno, 2020).

A further barrier experienced in South Africa is the fragmented culture between project stakeholders (Froise, 2014). Organisations in South Africa produce information in silos, resulting in a lack of coordination, collaboration and teamwork when working on a project (Harris, 2019). Companies are competitive and unwilling to share more information than is required by the contract. This silo mentality results in duplication of work, errors, lack of information and repetitive tasks that do not add much value to the project (Froise, 2014). Perhaps the most prominent cultural or social barrier in South Africa is the industry's reluctance to change (Akintola *et al.*, 2017; Chimhundu, 2015; Froise, 2014), which has a tremendous impact on digital transformation.

2.3.7 Lack of government support

The government provides limited support to promote or guide BIM implementation in the SACI, making private organisations and entities the current drivers for BIM development (Akintola *et al.*, 2017), such as the SA BIM Institute and Autodesk. These entities are profit-driven, which means that their objectives are not necessarily aligned with the performance or health of the entire industry. In 2014, Kiprotich (2014) found that the government still had no plans to mandate BIM for public projects, and it seems that this has not changed since. The Council for the Built Environment (CBE), the Construction Industry Development Board (CIDB) and the Department of Public Works (DPW) are together responsible for providing guidance and regulating the SACI. However, their absence in support regarding BIM implementation raises concerns (Akintola *et al.*, 2017).

The absence of government support could be due to their lack of awareness (Akintola *et al.*, 2017) or, according to Meno (2020), it could be due to the perceptions of government bodies that technology adoption reduces labour. The perception that BIM adoption would reduce jobs contradicts some government strategies that promote job creation, such as the Expanded Public Works Programme (EPWP) and the National Development Plan (NDP) 2030. One government initiative to promote job creation requires a contractor to allocate 30% of the project cost to manual labour (Meno, 2020). The government's current objectives are enforced through the CIDB, and it is to create jobs and for tenderers to meet the BBBEE requirements (Akintola *et al.*, 2017).

Government support is critical for BIM implementation. Firstly, since they are the largest clients in the construction sector, and secondly, because government policies and regulations are critical drivers of uniform BIM implementation across the industry (Gu & London, 2010; Porwal & Hewage, 2013). Therefore, a lack of government support and regulations could stall BIM adoption (Migilinskas, Popov, Juocevicius, *et al.*, 2013; Wong, Wong & Nadeem, 2011).

2.3.8 Lack of support and drive from all project stakeholders and industry institutions

McAdam (2010) further confirms the importance of the government in providing support for BIM implementation, as mentioned earlier, but also motivates the importance of partnering between the private and public sectors to drive BIM implementation. Many South African studies have shown a fragmented, inconsistent uptake of BIM in the construction industry. Designers and managers predominantly adopt BIM while other project stakeholders lack

awareness and knowledge of BIM processes (Chimhundu, 2015; Froise, 2014; Kekana *et al.*, 2015). This fragmented uptake of BIM creates silos in the industry and confuses project stakeholders on exchanging project information via BIM (Harris, 2019; Howard & Björk, 2008; Kane, Palmer, Phillips, *et al.*, 2015).

Akintola *et al.* (2017) confirm that professional registration councils that regulate architecture, engineering, project management and quantity surveying are not driving or promoting BIM. The Association of South African Quantity Surveyors (ASAQS) and the South African Council for Architecture Profession (SACAP) show some interest in BIM, such as promoting BIM Continuous Professional Development (CPD) courses and promoting research in BIM. However, all industry and regulating bodies do not make a consistent and collective effort to drive BIM. Govender (2018) confirmed that there is still a lack of information on BIM and IPD published by industry associations, which leads to a general lack of awareness in the industry and discourages organizations from adopting digital systems. The fragmented adoption of BIM is, among other things, due to a lack of support and drive from industry institutions and the partnering of private sector stakeholders.

2.3.9 Ineffective traditional procurement system

The traditional procurement system in South Africa results in silos among project stakeholders, such as between designers and contractors, which leads to duplication of work, change orders, time and cost overruns, and disputes (Govender, 2018). With regards to BIM implementation, architects would perhaps use BIM for 3D visualization and documentation while other project stakeholders work independently without using BIM (Ogwueleka & Ikediashi, 2017). Hence, the collaboration aspect of BIM is not utilized.

In addition, large portions of construction work are subcontracted (Hlahla, 2013), which further complicates BIM implementation. Even if the main contractor decides to implement BIM in a project, the sub-contractors will not necessarily have the same digital capability or financial capacity to implement BIM, hindering optimal BIM implementation and increasing project costs.

Froise (2014) confirmed the weaknesses of South Africa's current procurement processes and standard contractual arrangements. Current procurement methods in South Africa discourage collaboration, limit the exchange of information between stakeholders, and effectively restrict BIM implementation (Froise, 2014). The problem with changing current procurement systems is that the SACI is reluctant to change from traditional to modern procurement methods (Akintola *et al.*, 2017; Chimhundu, 2015).

2.3.10 Summary on challenges faced in South Africa

Table 3 summarises the BIM implementation challenges identified above and how the literature supports them. These challenges are further discussed in Chapter 6, where they are compared with the interview findings.

Table 3: Summary of the challenges for BIM implementation in South Africa

Challenges	Source from Literature
Lack of BIM competency in industry and education	(Chimhundu, 2015; Kekana <i>et al.</i> , 2015; Meno, 2020; Moodley <i>et al.</i> , 2016; Mtya, 2019; Pillay <i>et al.</i> , 2018; Tabesh, 2015)
Lack of BIM research and awareness	(Chimhundu, 2015; Froise, 2014; Govender, 2018; Kekana <i>et al.</i> , 2015; Kiprotich, 2014; Meno, 2020; Mtya, 2019)
Lack of industry guidance and leadership for BIM implementation	(Akintola <i>et al.</i> , 2020; Chimhundu, 2015; Wortmann <i>et al.</i> , 2016)
High implementation costs and uncertainty in returns	(Akintola <i>et al.</i> , 2017; Chimhundu, 2015; Kiprotich, 2014; Meno, 2020)
Lack of a legal framework	(Akintola <i>et al.</i> , 2017; Chimhundu, 2015; Froise, 2014; Meno, 2020)
Cultural and social barriers	(Akintola <i>et al.</i> , 2017; Chimhundu, 2015; Froise, 2014; Harris, 2019; Meno, 2020)
Lack of government support	(Akintola <i>et al.</i> , 2017; Chimhundu, 2015; Kiprotich, 2014; Meno, 2020)
Lack of support and drive from all project stakeholders and industry institutions	(Akintola <i>et al.</i> , 2017; Chimhundu, 2015; Froise, 2014; Govender, 2018; Harris, 2019; Kekana <i>et al.</i> , 2015)
Ineffective traditional procurement system	(Akintola <i>et al.</i> , 2017; Chimhundu, 2015; Froise, 2014; Govender, 2018; Ogwueleka & Ikediashi, 2017)

2.4 Review of initiatives or strategies for BIM implementation in South Africa

Strategies and recommendations were identified by previous research to mitigate the BIM implementation challenges faced in South Africa. These strategies form part of this research's second objective and serve as a foundation to develop new strategies and recommendations for the industry. From studying the South African literature on BIM implementation, common themes were identified.

The strategies are discussed in this section according to these identified themes:

- develop national standards and guidelines,
- develop and promote education and training programmes,
- promote research and development,
- government support,
- support from industry stakeholders, and
- explore alternative procurement routes.

2.4.1 Develop national standards and guidelines

A national BIM standard is essential for BIM development and project interoperability in South Africa (Akintola *et al.*, 2017; Chimhundu, 2015; Mtya, 2019). There are many global standards and guidelines available all over the world, but AECO companies in South Africa need specific guidance to adopt and implement BIM locally. Guidance can be any information that will facilitate or accelerate BIM adoption and implementation, such as BIM standards, successful local BIM processes, case studies, guidelines for BIM implementation, change management strategies and firm restructuring (Kiprotich, 2014; Meno, 2020).

Mtya (2019) recommends that more data be collected on best practices of successful BIM use and implementation strategies in South Africa to help establish guidelines, develop standards, and compile policies for BIM implementation.

Akintola *et al.* (2017) emphasise the need for a selected group of BIM experts, government officials and industry professionals in South Africa to develop jointly agreed upon, country-specific BIM standards that meet local challenges. They suggest that standards should consider local challenges but be adopted from existing national or international standards (Akintola *et al.*, 2017).

Many countries have adopted ISO 19650 as a national standard and included an annexure that meets local specifications. Wortmann *et al.* (2016) stated that the government should drive such an industry standard for widespread adoption.

2.4.2 Develop and promote education and training programmes

BIM education and skills development are the most critical aspects of BIM adoption in the industry (Kekana *et al.*, 2015). The full benefits of BIM will not be experienced if users are not sufficiently trained (Froise, 2014). Professionals from the industry need to be informed and educated about modern technologies and processes, which can be done through seminars and workshops (Meno, 2020). Companies should allocate funds to educate and reskill staff (Meno, 2020). Kiprotich (2014) suggests that software developers should provide local training in respective fields for BIM use. Froise (2014) identifies the opportunity for new companies to provide BIM training or BIM consulting to South African firms.

Training is needed to implement BIM and prepare the workforce for new processes, but this is expensive and tedious (Meno, 2020). Meno (2020) recommends incorporating digital skills in higher education curricula to prepare graduates for the present industry demands. This will reduce the time and money spent on courses and training required to upskill workers. Several studies have found a shortage of BIM skills taught in South African universities (Kiprotich, 2014; Pillay *et al.*, 2018; Tabesh, 2015). Therefore, an effort must be made to incorporate BIM in tertiary education of all built environment programmes (Mtya, 2019).

Similar to Mtya (2019), Moodley *et al.* (2016) recommended that the industry needs an education and training program for widespread BIM implementation. Pillay *et al.* (2018) recommend that built environment faculties collaborate and introduce a BIM implementation strategy to teach students the necessary skills they require to meet the current industry demand (Pillay *et al.*, 2018). Kiprotich (2014) states that the drive should come from the government and spread to all universities. In addition, higher learning qualifications should become BIM accredited, which would allow the BIM profession to grow and become recognised in the industry (Chimhundu, 2015).

2.4.3 Promote research and development

Country-wide BIM adoption is a phased process that requires time. Similar to digitalisation, as proposed by Mtya (2019), this process should be supported by continuous research and data collection to develop and update guidelines and policies as adoption rates increase, maturity

increases, and the technology develops. Chimhundu (2015) confirm this by stating that continuous research is needed and that BIM adoption rates need to be measured over time. Froise (2014) states that government bodies such as the CIDB should release more information from research done on BIM, raise awareness, educate the industry, and encourage the industry to adopt BIM. Funds should be explicitly allocated toward research and development in BIM (Meno, 2020). More funding for research will become available as soon as the industry becomes more aware of BIM (Kiprotich, 2014). Froise (2014) emphasises the need to raise awareness of international trends amongst contractors and the entire supply chain. Chimhundu (2015) propose that conferences and workshops are effective ways to raise awareness in the industry.

Yan & Damian (2008) recommend that a collection of case studies that show the benefits of BIM and successful BIM risk mitigation strategies, will attract investors to invest in BIM. Their recommendation corresponds with Singapore's IDD implementation plan that promotes BIM pilot projects, which is further discussed in Section 3.1.4. Chimhundu (2015) emphasise the need for a trusted national source to provide BIM information such as BIM libraries, data exchange frameworks and BIM guidelines. In addition, firms need to be encouraged to adopt BIM, even smaller businesses. Firms can be encouraged by providing adequate training and implementation guides and for software developers to release better suited and more affordable packages to accommodate smaller companies (Chimhundu, 2015; Kiprotich, 2014; Mtya, 2019).

2.4.4 Government support

Froise (2014) and Akintola *et al.* (2017) emphasise the importance of government intervention for successful countrywide BIM adoption in South Africa. One example is the UK government, which had the most structured approach to BIM adoption (Akintola *et al.*, 2017), and led BIM adoption with a strategy, policies, and BIM mandates on public works projects (Froise, 2014). Their approach is further discussed in Section 3.1.5. Government policies in the form of enforcement acts, national standards and regulations, have proven to drive successful BIM adoption in many countries over the world (Froise, 2014). Kiprotich (2014) confirm that the government should lead national BIM adoption strategies to develop BIM regulations and BIM inclusions in construction contracts.

Akintola *et al.* (2017) propose that the government start with incentives to raise awareness and motivate BIM implementation on public projects before implementing a BIM mandate. Incentives such as tax reliefs can encourage BIM implementation (Kiprotich, 2014).

Furthermore, the government should consider BIM mandates on public projects (Froise, 2014; Harris, 2019). The government should include BIM in their contracts for public projects (Chimhundu, 2015). Harris (2019) propose that the government enforce minimum BIM requirements in the form of standards for projects above a specific value to promote BIM implementation. Pillay *et al.* (2018) and Kiprotich (2014) highlights the importance of a government-led strategy to introduce BIM in all built environment universities in South Africa.

Mtya (2019) propose a BIM advisory board to help the government make informed decisions about BIM strategies and country-wide BIM adoption. The BIM advisory board should represent professionals from all stakeholders of the construction industry. It can consist of government officials, professional councils, people from academia, industry institutions and voluntary associations that can represent the built environment in South Africa (Mtya, 2019). Akintola *et al.* (2017) share the idea of Mtya (2019) to form a selected group of people from different stakeholders in the industry to develop standards and drive national BIM implementation. This board can be essential in making important decisions such as BIM adoption strategies, mandates, regulatory frameworks for the industry, and BIM to be incorporated in academia, as proposed by Pillay *et al.* (2018).

Suppose the South African government adopts or mandates BIM on public projects. In that case, it will not only lead to higher levels of efficiency and quality in project delivery (Chimhundu, 2015), but it will minimise corruption and misuse of taxpayer money due to the transparent nature of BIM processes (Froise, 2014). On the contrary, if the South African government does not make an effort to encourage BIM implementation, the industry will remain fragmented, global markets will become more competitive and take work from local organisations (Froise, 2014). Moreover, professionals in South Africa will not have the required skillsets to work according to international industry standards (Moodley *et al.*, 2016).

2.4.5 Support from all industry stakeholders (institutions, professional councils, regulatory bodies, policymakers, software developers, private AEC companies)

The current drive regarding BIM implementation in South Africa seems to be coming from the BIM Institute, the BIM Academy Africa and software developers (Natspec, 2019). According to a global BIM education report released by Natspec (2019), the BIM Institute has been communicating with universities, software developers, and public entities and are releasing BIM education courses to upskill the industry. However, the BIM Institute operates separately from the government and software developers (Natspec, 2019). Therefore, there is still a lack of collaborative efforts between the influential industry stakeholders to promote BIM.

BIM implementation requires a joint effort from the private and public sectors. All organisations, including project stakeholders, software developers, regulatory bodies, professional bodies, and others, have roles. South African government agencies provide no information on BIM and IPD, which contrasts with other countries with much information on these topics (Froise, 2014). Froise (2014) recommended that these agencies be introduced to international trends in similar organisations and follow their example.

Government agencies should increase BIM awareness through events such as BIM training workshops (Chimhundu, 2015). Industry associations should raise awareness in the industry by releasing more information on BIM and IPD, which will motivate BIM adoption in organisations and on projects (Govender, 2018). Industry bodies responsible for legislation and professional registration in South Africa should lead BIM implementation (Kiprotich, 2014). Regulating authorities in the construction industry can also enforce BIM mandates (Govender, 2018).

Although an enormous responsibility falls on the government, regulatory bodies, industry institutions and private sector owners all have a critical role in accelerating national BIM adoption (Kiprotich, 2014). Similar to Kiprotich (2014), Meno (2020) agrees that strategic partnering amongst the government, policymakers, academia, private investors and public investors is required for successful and widespread BIM implementation. Froise (2014) confirms the benefits of partnering and encourages stakeholders across the supply chain to recognise the opportunity and benefits that will be gained by BIM implementation and partnering.

Another study recommends digital partnering amongst firms for optimal digitalisation in South Africa (Aghimien, Aigbavboa, Oke, *et al.*, 2020). Mtya (2019) propose establishing a technical BIM advisory board consisting of software and technology specialists and professionals in the construction industry that should report to a BIM advisory board (Mtya, 2019). Mtya (2019) also recommends a collection of BIM resources located in one location, comprising BIM libraries, guidelines, standards, case studies, supporting the South African industry in BIM implementation, which is similar to the recommendation of (Chimhundu, 2015).

2.4.6 Explore alternative procurement routes

The weaknesses in South Africa's current procurement system and contractual arrangements were identified by many previous studies (Froise, 2014; Govender, 2018; Ogwueleka &

Ikediashi, 2017). Ogwueleka & Ikediashi (2017) recommend that the procurement system in South Africa be more integrated to promote partnership, collaboration and transparency. Meno (2020) states that government procurement specialists should be aware of the benefits of digitalisation on construction projects and explore alternative procurement systems that accommodate modern technology, leading to a faster tendering process and encouraging transparency.

The ideal approach to project delivery is IPD, but Govender (2018) recommends that organisations start following a more integrated procurement route, which will encourage collaboration and integration in a project and reduce repetitive work in silos. Likewise, Froise (2014) identifies the non-value adding tasks and inefficiencies seen on traditional projects and recommends that clients become aware of the advantages of BIM and a more collaborative procurement system, which will save money and prevent uncertainties and disputes.

The UK has increased BIM adoption by encouraging collaborative contractual arrangements. South Africa could follow their lead by aligning legislation and contracts to allow collaborative teams and strategic partners to collectively tender for work as a team.

2.4.7 Summary on strategies and initiatives for BIM implementation in South Africa

Table 4 shows the main points taken from past literature on BIM implementation in South Africa. These proposed strategies and initiatives will serve as a basis to decide on recommendations for BIM implementation in South Africa.

Table 4: Summary of the proposed strategies and initiatives for South Africa

<p>Develop national standards and guidelines for local BIM use:</p> <ul style="list-style-type: none"> - Adopt and change international standards and BIM guides to address local challenges. - Release information on best practices, BIM implementation guidelines, change management strategies, case studies. - Case studies can assist in developing guidelines and standards. - Standards should be a jointly agreed-upon document by a carefully selected group of BIM experts, government officials and industry professionals.
<p>Develop and promote education and training programs:</p> <ul style="list-style-type: none"> - Seminars and workshops to promote modern trends. - Allocate funds to educate and reskill staff. - Training provided by software developers for all project stakeholders.

- BIM consulting and training should be available.
- Built environment faculties should collaborate and introduce a BIM implementation strategy for built environment programs.
- BIM accreditation from educational institutions.

Promote research and development:

- BIM implementation requires continuous research to develop and update standards, guidelines and policies.
- Raise awareness to encourage industry to adopt BIM through seminars, conferences and workshops.
- Raise awareness across the industry supply chain.
- More funds dedicated to BIM research and development.
- Release BIM information such as case studies, guides, BIM libraries.
- Software companies should be encouraged to provide affordable packages, especially for smaller firms.

Government support:

- Have a structured approach or strategy to implement BIM
- Introduce policies and mandates for public projects.
- Government incentives that promote BIM implementation, such as tax reliefs.
- Mandate BIM for tertiary education.
- Develop BIM advisory board to assist the government with BIM implementation.

Support from industry stakeholders:

- Joint effort from the private and public sector.
- Government agencies should be informed of international trends and release relevant information.
- Regulating bodies, professional councils and policymakers need to drive BIM implementation.
- These institutions should join with academia to promote country-wide BIM implementation.
- A technical BIM advisory board to assist BIM advisory board.
- Freely available resources on BIM to be released by a trusted source.

Explore alternative procurement routes:

- more integrated, collaborative, transparent.
- promote partnering and joint tendering.
- encourage collaborative contracts like design-build.
- policymakers and regulatory bodies should address legal implications of BIM such as IP and design liability.

2.5 Conclusion of literature review

The literature review covered the theoretical background about BIM, a review of the related global and local literature, the challenges faced in South Africa regarding BIM implementation and the solutions proposed to mitigate these challenges. The information obtained from the literature is compared to the research findings in Chapter 6.

3 International BIM implementation

This chapter aims to provide the reader with information about international BIM implementation and explain how South Africa differs from these countries. First, Section 3.1 covers BIM implementation strategies in Australia, Ethiopia, Ireland, Singapore, the United Kingdom and the United States. Then, Section 3.2 includes a discussion about the nature of the SACI.

3.1 BIM implementation strategies per country

Since South Africa does not have a national BIM implementation plan or strategy, South Africa now has the advantage of developing a strategy based on what other countries have done. Therefore, this section covers some of the actions taken by a few selected countries in terms of BIM strategies, programmes, and initiatives.

3.1.1 Australia

Although public organisations led Australia's BIM development, both the public and private sectors were motivated to speed up BIM adoption in the country (Hadzaman, Takim & Nawawi, 2015). After a series of studies, reports, and consultation workshops, funded by buildingSMART Australasia, Australia's Department of Industry, Innovation, Science, Research and Tertiary Education (DIISRTE) and others, the need for a national action plan to accelerate BIM adoption became clear (buildingSMART Australasia, 2012). In 2012, buildingSMART Australasia released a National Building Information Modelling Initiative, which includes an implementation plan summarises various work programmes for the Australian Government and the industry to help accelerate BIM adoption (Hadzaman *et al.*, 2015). The implementation plan included seven main work programmes: procurement, BIM guidelines, education, product data and BIM libraries, process and data exchange, regulatory framework, and pilot projects.

The Australian construction industry is continuously assessing, improving and upskilling their BIM processes with the help of the Australian BIM Advisory Board (ABAB), NATSPEC, Standards Australia and buildingSMART Australasia. These institutional bodies were established by the Australian Construction Industry Forum and the Australian Procurement and Construction Council. ABAB is responsible for guiding the industry, government and academia by coordinating the development of BIM requirements, standards and best practices (Australian BIM Advisory Board, 2021).

3.1.2 Ethiopia

The Ethiopian Construction Project Management Institute (ECPMI) produced a “Roadmap for BIM adoption and implementation” to explain their action plan to drive BIM adoption in Ethiopia in a systematic approach (Ethiopian Construction Project Management Institute, 2019). Since Ethiopia is the first African country to release a national BIM implementation plan (Natspec, 2019), it would be helpful to use it as a reference when considering BIM development strategies for South Africa. The Ethiopian BIM roadmap included 18 initiatives categorised according to the following areas: collaboration, incentive and proven benefit, standards and common practices, legal and insurance, information sharing and handover, promotion and education, sufficient digital capability and vendor support, risk management, and regional competitiveness. The ECPMI also highlighted the role of the public sector regarding BIM implementation, as shown in Figure 10.

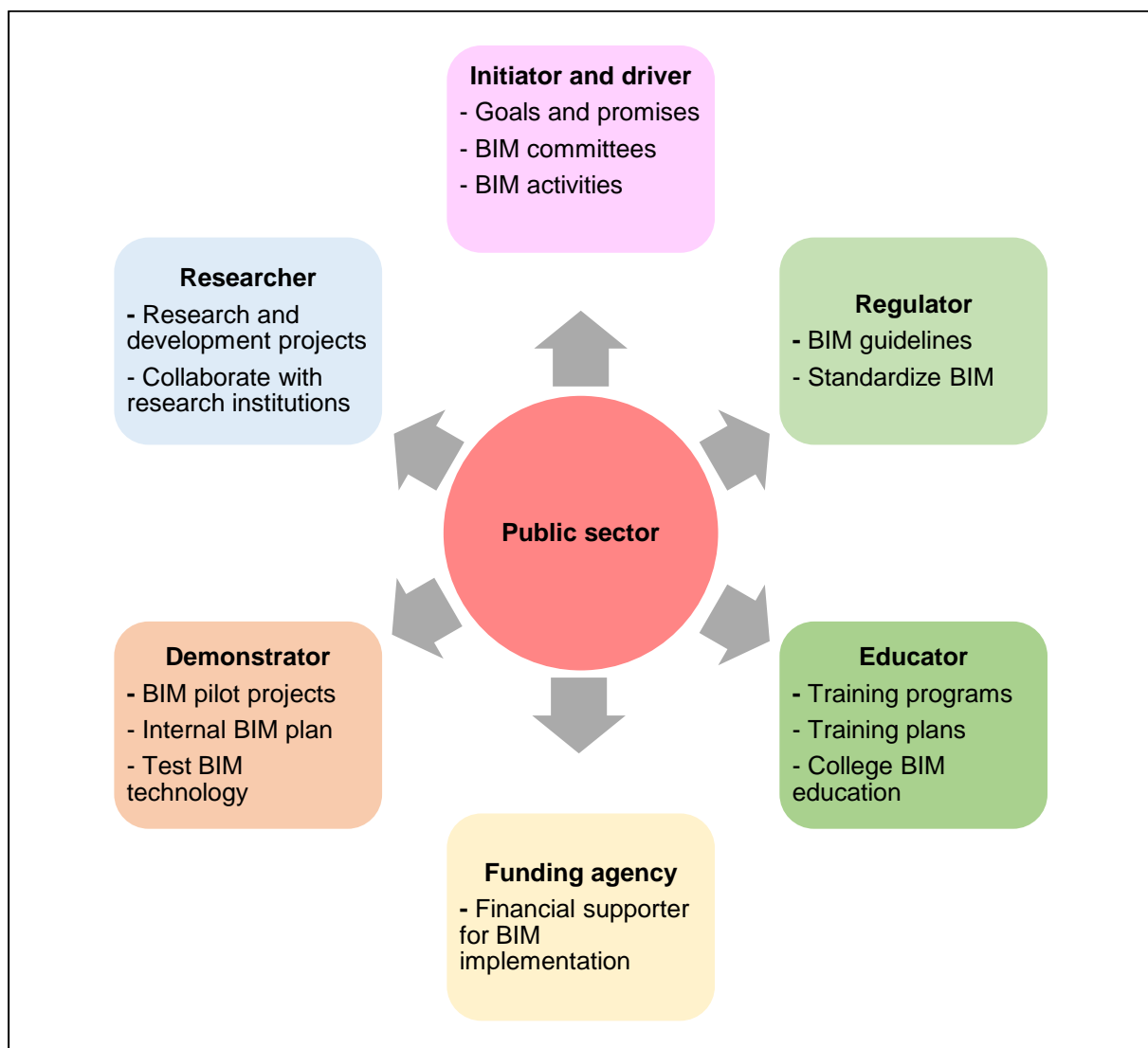


Figure 10: Public sector roles for BIM implementation, adapted from ECPMI (2019)

3.1.3 Ireland

The National BIM Council (NBC) of Ireland released a Digital Roadmap in 2017. The NBC consists of a committee of clients and representatives across the construction industry supply chain, and their key deliverable was to develop the National Roadmap to guide the digital transition in the built environment of Ireland (National BIM Council, 2017).

The roadmap is divided into four categories: leadership, standards, education & training and procurement. Each category contains several actions, events, or initiatives that will help improve digital uptake in the industry and improve the industry's performance. The Ireland roadmap also contains a second section where the key role-players in the industry responsible for particular events/activities are identified (National BIM Council, 2017).

3.1.4 Singapore

Digital transformation has been driven in Singapore since 2000 by the Construction and Real Estate Network (CORONET) program, which the government established to promote the use of information technology (Smith, 2014). Singapore's Building Construction Authority (BCA) is currently driving the digital transition in Singapore's construction sector (Smith, 2014). In 2008, the BCA implemented the first BIM model-based e-submission system to encourage BIM use in the industry (McGraw Hill Construction, 2014a).

The BCA also released a national BIM guide in 2013, which guides firms adopting BIM and covers topics such as change management, BIM standards and people management (Building and Construction Authority, 2013). They have also released many other resources, such as "BIM Particular Conditions" in 2015, containing legal conditions that can be added to construction contracts where BIM is implemented (Building and Construction Authority, 2015).

The latest strategy involving BIM implementation is the Integrated Digital Delivery (IDD) implementation plan, which guides the industry from the IDD steering committee and the Future Economy Council (FEC) Built Environment Sub-Committee (Building and Construction Authority, 2018). S\$4 million was set aside as part of the IDD implementation plan to fund digital platforms that should assist construction firms to accelerate their digitalisation (Building and Construction Authority, 2018).

The IDD implementation plan consists of three main action plans with key initiatives, which is paraphrased below (Building and Construction Authority, 2018):

1. **Promote and develop IDD by demonstrating it through actual projects:** The target is to pilot 40-60 IDD projects by 2020, reaching 150 firms in Singapore and digitally upskilling 300-400 industry professionals to become IDD leaders. In addition, the BCA released an IDD Leaders' Quick Start Guide to assist the management of firms in delivering an IDD project.
2. **Develop IDD platforms, solutions, and standards:** This action plan involves a Grant Call for technology firms to develop Construction Digital Platforms (CDP) that meet local challenges. The idea is for technology firms to collaborate with built environment firms and to develop digital platform solutions that meet the local challenges in Singapore's built environment. Current platforms and solutions that are commercially available may require further enhancements or modifications since it is aimed at the global market and not in Singapore.
3. **Increase IDD competency:** This involves the availability of an extensive range of IDD training programmes and courses facilitated by the BCA Academy, which aims to uplift the IDD competency in the industry.

3.1.5 United Kingdom

The United Kingdom (UK) is regarded as the global leader in BIM adoption and implementation because of their structured approach (Akintola *et al.*, 2017). The UK government released a document in 2013 that set out a strategy that by 2025, they want to (1) decrease construction and asset lifecycle costs by 33%, (2) reduce the time taken for construction projects from onset to handover by 50%, (3) reduce greenhouse gas emissions by 50% and (4) reduce the trade gap for exports and imports of construction materials by 50% (HM Government, 2013).

The UK government realised the importance of BIM in reaching these goals. Therefore, they stated that all government-funded projects must use BIM at a level 2 maturity by 2016, no matter the size of the project. By 2025 it is expected that they will move to a level 3 BIM maturity (HM Government, 2013).

The UK also released the latest international BIM standard through the UK BIM Task Group, ISO 19650, which has been accepted as the official European BIM standard (The British Standards Institution, 2019) and has been adopted by many countries around the world. The BIM Task Group had a significant role in the UK's construction strategy involving the strategic priority in Construction 2025, "smart construction and digital design". The strategy set out by

the UK government accelerated BIM adoption since the National Building Specification recorded an increase of BIM users in the UK from 11% in 2010 to 73% in 2020 (National Building Specification, 2020; Royal Institute of British Architects, 2011).

The first BIM strategy in the UK was released in 2011 by the Department of Business, Innovation and Strategy (BIS) (BIM Industry Working Group, 2011). The strategy covered the following main topics: exploiting digital capabilities, legal, contracts and insurance, delivery standards and processes, “education, training and support”, improved information handover, information use and benefits, communication and institutional support, investment, and programme.

The Digital Built Britain Level 3 BIM is the UK’s latest strategic plan that builds on the BIS BIM strategy and Construction 2025 (HM Government, 2015). The Digital Built Britain vision does not only involve stakeholders in the construction sector, but it involves a national movement covering other sectors such as transport, education, health and finance and includes smart cities and the digital economy (HM Government, 2015). For the Digital Built Britain agenda, it is not only the construction sector that is involved, but other sectors such as transport, education and health also fit into this plan. The Digital Built Britain strategy replaces the BIS BIM strategy and provides opportunities and innovations such as Internet of things, AI, smart cities and data analytics, to name a few (Royal Institution of Chartered Surveyors, 2020). However, this strategy is perhaps somewhat too advanced to be adopted by South Africa, which is still at an infant BIM adoption stage.

3.1.6 United States

The General Services Administration (GSA) has played a major role in adopting and implementing BIM in the US. Since the release of their first national BIM programme (National 3D-4D-BIM Program) in 2003 (Smith, 2014), they have been promoting and developing BIM.

The GSA developed BIM adoption initiatives, guidelines, and standards recognised internationally and led the industry as a public client with over 8700 buildings (buildingSMART Australasia, 2012; Edirisinghe & London, 2015). In 2007 a minimum BIM requirement was put in place for all final concept models of large projects (Edirisinghe & London, 2015). Penn State University was awarded a research programme to develop BIM in the US, and successfully developed industry standards and guidelines such as a “BIM planning guide for facility owners”, “BIM project execution planning guide”, “BIM process maps” and “BIM uses” (BIM Industry Training Group, 2016).

As part of the National 3D-4D-BIM Program, the GSA published a series of 8 BIM guides that assisted the industry with BIM implementation, which included a 3D-4D-BIM overview, 3D laser scanning, spatial program validation, energy performance and operations, 4D phasing, building elements and facility management and circulation and security validation (Edirisinghe & London, 2015). The National Institute of Building Sciences (NIBS) have produced the national US BIM standards with the buildingSMART alliance, which is called the National Building Information Modelling Standard (NBIMS) (National Institute of Building Sciences, 2015).

The most recent project to accelerate BIM usage in the USA is the US National BIM Program (Cube, 2021). The program involves developing a new information standard by building upon the existing NBIMS and providing a platform to facilitate digital innovation in the built environment. The project will be led by a selected committee (the National BIM Program Steering Committee) consisting of business owners and industry representatives from the public and private sectors, including design, construction, asset operation, technology, manufacturing sectors, and software vendors (Cube, 2021).

3.1.7 Conclusion of global BIM implementation strategies

Although the approach of each of the abovementioned six countries slightly differed, there were many similarities. For example, a BIM steering committee or BIM task group was developed in Australia, Ireland, United Kingdom, and the United States. Furthermore, every country had a national action plan regarding a strategy, a roadmap or a programme. However, their strategies differed in their focus areas. For example, where Singapore's IDD implementation plan focused on three main initiatives, Ethiopia's roadmap consisted of 18 initiatives. It seemed that countries such as the USA and the UK gradually increased their BIM uptake and updated their BIM strategies or implementation plans as they progressed up the BIM maturity ladder. The adoption of these global strategies for South Africa is discussed later in the study.

3.2 The nature of the SACI

Some of the global BIM implementation strategies and initiatives were discussed in Section 3.1. However, the progress of BIM uptake is still relatively low in South Africa compared to these countries (Govender, 2018). Although there are groups of architects, contractors, and engineers leading BIM implementation in South Africa, these developments are not

widespread and are performed in silos in the industry (Harris, 2019). Therefore, it is essential to understand the SACI to determine why. This section aims to provide the reader with the context of the South African construction environment. First, the industry demographics and makeup of the construction industry are discussed. Then, the regulation of the procurement system is briefly covered. Finally, some challenges that significantly impact the SACI are discussed, such as corruption and skills shortages.

3.2.1 Industry demographics

The construction industry in South Africa is currently providing jobs to over 1.3 million people and is contributing about 4% to the country's Gross Domestic Product (GDP) (Construction Industry Development Board, 2020; Veitch, 2020). In 2020, public projects made up 57% (R62 billion) of all construction projects, while 43% (R46 billion) was private (Construction Industry Development Board, 2021). The projects in South Africa are categorised according to civil works, non-residential buildings and residential buildings. In 2020, 51% of the projects were awarded to civil works, 22% to non-residential projects and 27% to residential projects (Construction Industry Development Board, 2021).

Contracting firms are categorised according to the CIDB's ranking framework, based on their track record and available capital (African Competition Forum, 2019). The ranking system consists of grades ranked from 1 to 9, determining if firms are eligible to tender for certain public projects. The number of contractor firms in South Africa, as recorded in March 2020, was 56 653, as shown in Table 5. The second column in Table 5 states the maximum tender value limit according to grade. For example, grade 1 contractors are only allowed to tender for projects up to R500 000. From Table 5, it is evident that grade 1 contractors take up the bulk of the industry at 83%. However, they typically lack skills and experience, according to the CIDB (2020). Grades 2 to 4 contractors are more established and operate locally, whereas grades 5 to 6 transition between provincial and local levels (Construction Industry Development Board, 2021). Grades 7 to 8 operate at a provincial or national level, while grade 9 contractors are often international organisations (Construction Industry Development Board, 2021).

In a study focused on BIM adoption in South African construction firms, Mtya & Windapo (2019) found that a construction company's grade is directly related to its organisational readiness to adopt BIM. Therefore, smaller contractors would find it more challenging to adopt BIM than larger contractors operating internationally. Since the bulk of the industry consists of smaller

contractors, Mtya & Windapo's (2019) findings confirm why the South African construction industry has such a low BIM uptake.

Table 5: Distribution of contractors per grade, data from the CIDB (2020)

Grade	Tender value limit	Number of registered contractors (March 2020)	Distribution (March 2020)	Distribution by public award value (Q1 2019 to Q4 2019)
9	No limit	86	0.2%	38%
7 & 8	R200 000 000	1134	2.0%	49%
5 & 6	R20 000 000	2435	4.3%	9%
2 to 4	R6 000 000	5921	10.5%	3%
1	R500 000	47077	83.1%	1%
		56653	100%	100%

The distribution by public award value as recorded between the first and fourth quarter of 2019 is also shown in Table 5. The contractors from grades 7 to 9 were awarded 87% of the public awards. 87% is a considerable amount of money given to the contractors that only make up 2.2% of the industry. Furthermore, according to the CIDB report of 2019/2020, most of the projects awarded in grades 7 to 9 are subcontracted to firms in grades 2 to 6. Mbachu (2008) claims that subcontractors handle about 85% of all building projects. Pillay & Mafini (2017) state that these demographics contrast with government initiatives since large amounts of money goes to large contractors, but small and medium-sized firms dominate the construction industry. Anugwo & Shakantu (2020) recognises the prominent role of small and medium-sized firms in the competitiveness of the South African economy. Thus, they recommend that more effort should be aimed at the survival and growth of these firms.

3.2.2 Procurement and regulation

In 1994 during the constitutional transformation in South Africa, a new public procurement system was adopted (Anthony, 2017). According to Anthony (2017), "*the construction industry was used as a model for procurement reform in South Africa*". Consequently, all public projects in South Africa are now heavily regulated by regulations and policies (Anthony, 2017). For example, all construction firms must register with the CIDB before tendering for public projects and adhere to their regulations (African Competition Forum, 2019). Furthermore, 57% of construction projects are publicly funded (Construction Industry Development Board, 2021), entailing the majority of the industry is heavily regulated.

The CIDB developed a framework with guidelines on procurement arrangements and contracts in the construction industry (Kwofie, Aigbavboa & Matsane, 2017). The four standard forms of contracts endorsed by the CIDB are Federation Internationale Des Ingenieurs Conseils (FIDIC), General Condition of Contracts (GCC), Joint Building Contracts Committee (JBCC) New Engineering Contract (NEC) (Mewomo & Maritz, 2015). However, the application of these contracts in South Africa seems to contrast with other countries. Matsane & Aigbavboa (2015) found that South African construction sites differ in collaborative practices from the global construction community. The relationships between project teams on South African construction sites were characterised as “antagonistic” by Matsane & Aigbavboa (2015). Therefore, Matsane & Aigbavboa (2015) identified the need to implement alternative procurement practices that promote collaboration. Similarly, Kwofie *et al.* (2017) state that some collaborative procurement practices are implemented in South Africa. However, project stakeholders still lack the understanding of collaborative practices vital to improving construction projects in South Africa.

3.2.3 General challenges in the SACI

The construction industry, in general, faces many challenges. However, according to Sibiya, Aigbavboa & Thwala (2015), the SACI faces more serious and complex challenges. These challenges could explain why South Africa is still behind developed countries regarding BIM uptake. Windapo & Cattell (2013) identified the following twelve challenges impacting the SACI:

- The capacity of the public sector
- Procurement practices and the capacity for sustainable empowerment
- Mismatches between available and required skills
- Poverty
- Availability of infrastructure
- High rate of failure of enterprises
- Poor technology use
- Availability of suitable land for construction
- Access to affordable credit and interest rates
- Increase costs of building materials
- Strict policies and regulations
- Critical global issues

Some of the abovementioned challenges could be regarded as general challenges in the construction industry. However, according to Sibiya, Aigbavboa & Thwala (2015), the challenges are magnified in South Africa. The South African unemployment rate, including people available to work but not actively searching, stands at 44.4%, the highest among 88 countries monitored by Bloomberg (Naidoo, 2021). The unemployment rate significantly affects the economy and the SACI and creates a snowball effect for more challenges. All of these challenges are not discussed in depth. However, some of the significant challenges impacting the SACI, such as the lack of skills and corruption, are discussed below.

Lack of skills:

Construction projects are complex and bespoke, requiring competent people, technical skills, and expert knowledge to execute effectively (Sibiya *et al.*, 2015). However, South Africa is suffering from a skills shortage which inhibits the growth of the construction industry. Pillay & Mafini (2017) found that the number of qualified skills in South Africa is receding every year. The decline in the skilled workforce is due to South Africa's poor education system and the increasing global competitiveness (Aghimien, Oke & Aigbavboa, 2019; Shikweni, Schurink & van Wyk, 2019). According to Shikweni *et al.* (2019), the graduate output per year is insufficient to support the skills needed in the industry. Hence, due to the skills shortage, construction projects depend on unskilled labour, which affects the quality of work and the business's success (Windapo, 2017). Furthermore, many contractors in South Africa may not have the technical or managerial skills required to run their businesses (Windapo, 2017).

Corruption:

Pillay & Mafini (2017) state that organisations that are struggling to remain profitable often turn to unethical practices to survive. Bowen, Edwards & Cattell (2012) state that corruption often occurs in South Africa when public officials engage in bribing and tender manipulation. Furthermore, contractors and all other project stakeholders were found to be involved in acts of corruption (Bowen *et al.*, 2012). Bowen *et al.* (2012) concluded that it would be difficult to eliminate corruption. However, improvements to the current procurement processes towards transparency and accountability could promote ethical practices in the construction industry.

3.3 Conclusion

The BIM implementation strategies adopted by six countries were studied, and similarities were identified. For example, these countries had a guiding body to lead BIM implementation and a clear BIM implementation strategy. On the other hand, South Africa has no national BIM implementation strategy or a nationally recognised body to lead the BIM movement. Therefore, the nature of the SACI was studied. It was found that South Africa has many challenges affecting BIM uptake, related to the industry demographics, skills shortages, corruption, and procurement, among others. These global BIM implementation strategies and their applicability to the SACI are further discussed in Chapter 6.

4 Methodology

In this chapter, the research approach, participant demographics, method of data collection, and data analysis are discussed. The research approach (Section 4.1) includes the reasoning behind the choice of research methodology. Section 4.2 covers the selection criteria of the research participants and the participant demographics. The data collection (Section 4.3) includes the design of the interview guide and the procedures followed to obtain the data from the participants. Finally, the data analysis (Section 4.4) describes how the researcher interpreted the data and used the data to contribute to the research findings.

4.1 Research approach

From the literature review in Chapter 2, it is observed that some studies had more forms of data collection than others. For example, the findings of Sun *et al.* (2015) and Kouch (2018) were only based on the data collected from literature. In comparison, other research findings such as Khosrowshahi & Arayici (2012) and Vidalakis *et al.* (2020) were based on three forms of data sources: literature, focus group interviews and surveys. Furthermore, it is observed that the studies with more forms of data collection had more robust results than those only considering literature. Therefore, the researcher aimed to collect data from at least one more source than literature.

The researcher had to decide whether to use quantitative or qualitative data and how the data will be collected. Mtya (2019) made use of quantitative data in assessing South Africa's BIM maturity and capability. However, the current study had more complex objectives which require a more profound understanding and cannot simply be quantified. Furthermore, considering the low understanding of BIM in South Africa, the researcher reasoned that a quantitative approach might yield inaccurate results. Therefore, a qualitative approach was developed, motivated by the need to gain a better understanding of BIM in South Africa. The main form of data being interviews with a focus group of BIM experts from the SACI. This approach is similar to Sahil (2016) and Akintola *et al.* (2017). Hence, these studies were used as guidance in developing the research methodology.

The qualitative approach chosen for this study is phenomenological, similar to the research by Sahil (2016). Leedy & Ormrod (2016) stated that a phenomenological study is “*a study that attempts to understand people's perceptions and perspectives relative to a particular situation*”. By conducting interviews with a focus group of BIM experts from South Africa, their perceptions and perspectives were used to gain better insight on BIM implementation in the industry.

The study is also exploratory, similar to Chimhundu (2015). Exploratory means that the research is evolving, and the researcher gains a better understanding of the phenomenon throughout the study. Leedy & Ormrod (2016) explains that an exploratory study usually has two phases. The first phase is where the researcher gains a better understanding of the phenomenon to form a basis upon which to build the second phase. The second phase involves a more structured and systematic qualitative approach. The developed research methodology was based on Leedy & Ormrod's (2016) explanation, as illustrated in Figure 11.

Phase one was where the researcher explored various sources of information to gain a better understanding of BIM. The first phase helped the researcher to select the focus group participants and develop an interview guide to conduct semi-structured interviews. Phase two entailed conducting the interviews, analysing the data and describing the data in a logical form. These phases are described in more detail in Sections 4.3 and 4.4.

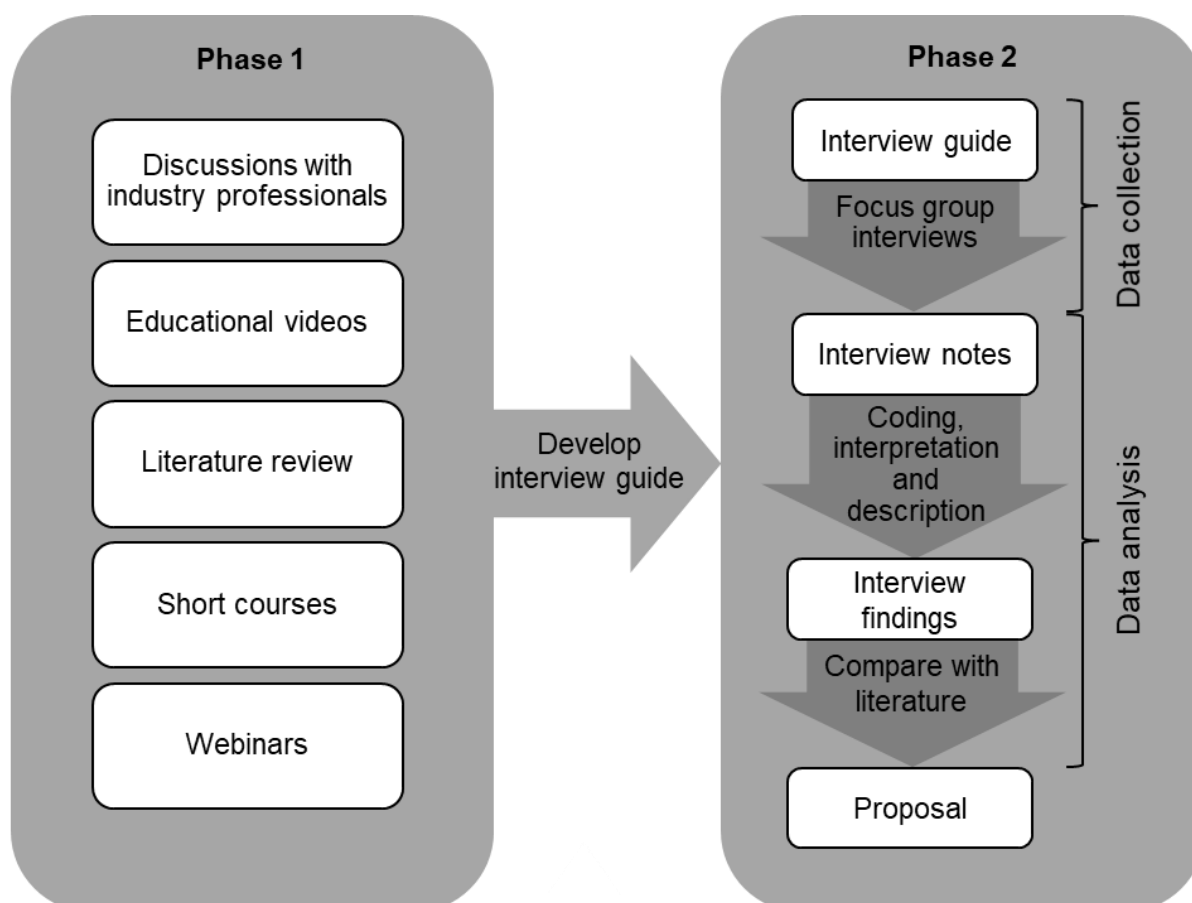


Figure 11: Research methodology flowchart (author)

4.2 Participant demographics

Since the main form of data was collected through the focus group interviews, the participants had to be carefully identified. The criteria followed when identifying participants were that they should have a comprehensive understanding of BIM and the SACI. However, finding BIM experts in South Africa was challenging due to the low number of mature BIM projects. Furthermore, different professionals work for different organisation types, and each experiences BIM differently. Therefore, it was decided that the focus group had to be diverse according to their field of experience to ensure that the findings were not biased towards a specific profession or group in the industry (such as asset owners, contractors or consultants). Therefore, nine diverse participants that meet the criteria were selected to represent the focus group. These participants were found through BIM networking events, BIM webinars, BIM projects and mutual connections.

The participants remained anonymous due to ethical considerations. However, some details of the participants are shown in Table 6 to describe their areas of expertise. Due to the lack of BIM experts in South Africa, two participants were from other countries (P8 and P9). These participants only met the criteria because they have lived or worked in South Africa. Furthermore, both have over ten years of BIM experience which was very difficult to find in South Africa. The participants' years of experience in BIM and the construction industry is visually illustrated in Figure 12. The collective BIM experience of all participants adds up to a total of 68 years. Their collective experience in the construction industry adds up to 163 years.

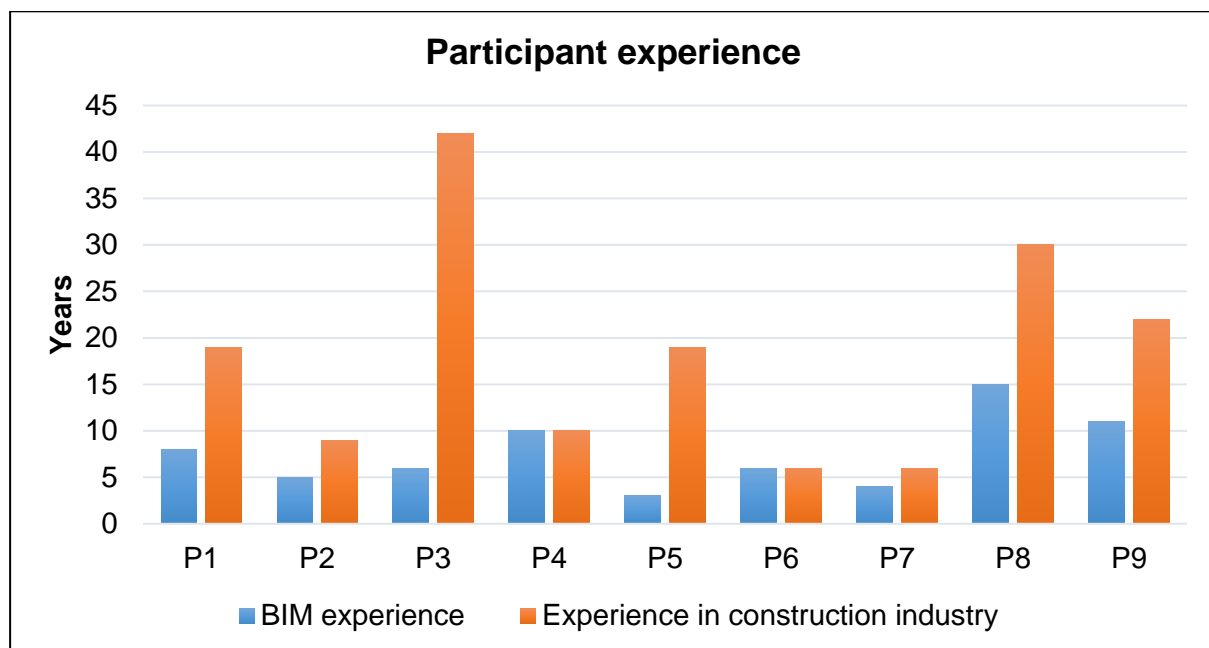


Figure 12: Participant experience with BIM and the construction industry

Table 6: Participant background and expertise

Code	Country	Background	Profession	Company type
P1	South Africa	Civil engineering background, from three continents. Working on government strategies to increase BIM implementation in local government.	civil engineer	client (public)
P2	South Africa	Civil Engineer. Experience on BIM projects abroad. Current business owner providing consulting for construction technology and digital transformation.	civil engineer	consulting (private)
P3	South Africa	Owner of project management consultancy providing BIM services.	project manager	project management (private)
P4	South Africa	Architect background. BIM experience abroad. Current work involves digital twin cities, city development strategies and lean construction practices.	researcher and consultant	education (public) and consulting (private)
P5	South Africa	Property developer working on an integrated BIM project in South Africa.	property developer	client (private)
P6	South Africa	BIM software consultant and vendor.	software specialist	software supplier (private)
P7	South Africa	Civil engineer and BIM champion, working on government projects.	civil engineer	client (public)
P8	Ireland	Architecture background. Many years of BIM experience. Contributed to developing Ireland's digital roadmap. Providing BIM services and consulting.	architect, BIM specialist/consultant	BIM consulting and support services (private)
P9	New Zealand	Digital engineer at a large consulting firm and running a BIM education business.	BIM manager, BIM specialist/consultant	consulting (private)

4.3 Data collection

The data collection is a critical phase of the study since it dictates the research findings. Therefore, specific measures were taken to ensure that the collected data was accurate. In addition, ethical clearance was obtained from the Research Ethics Committee (REC) of Stellenbosch University prior to any contact made with people from the industry.

Phase one of the methodology could be viewed as the informal start of the data collection process (see Figure 11). During this phase, the researcher gained a better understanding of BIM implementation through literature, webinars, short courses, educational videos, and discussions with industry professionals. This phase was critical for the researcher to (1) select the focus group, (2) develop the correct interview guide, (3) conduct meaningful interviews and (4) correctly interpret the data. Furthermore, due to the rapid transformation of BIM in the construction industry, the literature alone did not contain the latest information about BIM. Therefore, sources other than literature were used to fully understand the phenomenon and its meaning for today's construction industry.

The researcher attended several virtual events, such as the Future of Connected Construction in South Africa and the Festival of BIM and Digital Construction (Oliver Kinross Productions, 2021). The Festival of BIM and Digital Construction is the most prominent virtual digital construction event globally, consisting of virtual presentations, panel discussions and case studies from construction professionals across six continents (Oliver Kinross Productions, 2021). In addition, the researcher gained further knowledge on the phenomenon through attending BIM short courses. These courses included a BIM fundamentals course involving basic BIM modelling and a BIM coordinators course entailing BIM management and coordination.

The final source of preliminary information collected in phase one involved informal discussions with professionals from the industry, including contractors, engineers, architects, BIM experts and academics. These discussions served as background knowledge about BIM in South Africa to give the researcher insight and guide the study in a meaningful direction. Using the knowledge gained in phase one, the researcher developed an interview guide (shown in Appendix 1) to conduct semi-structured interviews in phase two. The interview guide questions were open-ended and strategically arranged to contribute to the flow of the interviews. In addition, since these questions were well-versed, it led to in-depth discussions requiring minimal input from the researcher, which reduced researcher biases.

The researcher had to conduct the interviews carefully to ensure that accurate data is collected and that the ethical protocols required by the REC are adhered to. Each participant was invited to participate via email and had to sign a consent form. The interviews were conducted via video call and took about one hour each. The researcher refrained from elaborating on the questions to avoid manipulating the participants by providing them with researcher biases. Although the interview guide provided some structure to the interviews, the discussions were often very unstructured, allowing the participants to elaborate on the phenomenon freely. However, due to the time constraints, the researcher often had to subtly direct the conversation back to the research focus by referring to the interview guide.

During each interview, the researcher compiled notes about the perceptions and opinions of the participants. The participants were often asked to repeat or explain a sentence if the researcher did not fully understand or could not keep up with taking notes. After each interview, the researcher revisited the notes and thoroughly interpreted and described the participant's perceptions, opinions, feelings and viewpoints. These interview notes were saved according to a codename for each participant to ensure they remain anonymous. Then, the notes were returned to the participants for them to review and edit. This step eliminated the researcher's biases and allowed the participants to rethink their answers and provide a more accurate account where needed.

4.4 Data analysis

The data analysis process started during the interviews since the researcher already started to interpret the participants' perceptions and took notes of the important and relevant points. The researcher's background knowledge (gained through phase one of the research methodology as illustrated in Figure 11) assisted with interpreting the participants' responses. No transcriptions or data analysis software were used since these do not consider the participants' voice tones and body language. Furthermore, manual notes eliminated repetitive statements or unnecessary noise. After compiling the interview notes, the notes were sorted according to each question from the interview guide. Therefore, each participant received their interview notes sorted according to the questions to review.

Once the reviewed notes were received back from the participants, the process of thematic analysis was followed. Thematic analysis is a standard method used by many researchers, such as Bowen *et al.* (2012), Kwofie *et al.* (2017), and Shikweni *et al.* (2019).

These six steps proposed by Braun & Clarke (2006) were used as guidance for doing the thematic analysis:

1. Familiarising yourself with your data
2. Generating initial codes
3. Searching for themes
4. Reviewing themes
5. Defining and naming themes
6. Producing the report

Firstly, the interview notes were iteratively read through to gain an understanding of the data. Secondly, initial codes were generated by making summarised notes on the interview notes. The third step involved working through the data with different codes and searching for common themes and relationships. This data was then moved to an online mind map application called Coggle. An example of the mind maps is shown in Appendix 2. The interview notes could then be organised in a mind map format according to the identified themes. This process helped the researcher to obtain a holistic understanding of the data. Step four involved reviewing the themes, which was made easier using the mind map application. Then, the themes were defined and named before describing the data in the report.

The thematic analysis process was done for each interview question. The responses for each interview question are described in Chapter 5 using thick description. Thick description entails that the researcher describes the participants' perceptions in detail and captures the phenomenon's complexity to provide readers with an in-depth and complete picture of the phenomenon, allowing them to make informed interpretations (Leedy & Ormrod, 2016).

After analysing the interview data, the findings were sorted according to the four objectives of the study in Chapter 6. Then, another thematic analysis process was followed for each objective, which entailed using the data from more than one interview question. Furthermore, the findings were compared with literature as a further means of validation. Finally, these findings are used to develop the final proposal described in Section 6.5.

5 Data analysis

This chapter presents the data analysis process. The interview responses are analysed in Section 5.1, where each question according to the interview guide is discussed. There were 11 questions in the interview guide. The researcher engaged in thick description, as described in section 4.4, by thoroughly describing the participants' responses for each question to ensure that an accurate and holistic account is portrayed. The interview response analysis involves discussions regarding the questions' aims, common themes, similarities and differences.

5.1 Interview response analysis

5.1.1 Question 1

*What is your current **understanding** of the concept of BIM?*

This question had two purposes. The first was to open the discussion with a relatively easy question to get the participants thinking and talking about BIM. The second purpose was for the researcher to learn about the participants' different perceptions about BIM. Due to the complex nature of the construction industry consisting of different projects, organisations and professions, the respondents had different BIM experiences. Therefore, this question assisted the researcher in interpreting the participants' opinions and viewpoints based on their understanding of BIM.

The researcher noticed a slight difference in the participants' perceptions about BIM. Although all participants seemed to have a mature understanding of BIM as a process that runs through the entire lifecycle of a built asset, their angle of approach differed. For example, some participants focused on the technical BIM modelling side, which is typically associated with the design phase of a built asset. Others focused on BIM as an information management process during the construction phase, involving coordination, collaboration, and management. Finally, some focused more on the operational phase of BIM, involving facilities management, digital twins, and smart cities.

It seemed that the participants' viewpoints about BIM slightly differed based on their experiences. Architects, engineers, and other consultants typically had a better understanding of BIM implementation at the design stage. Contractors and project managers had a mature understanding of BIM applied during the construction stage. Asset owners had a better understanding of BIM applied in the operational phase. The different viewpoints helped the

researcher to obtain a holistic view of BIM implementation. Question 1 served its purpose since it naturally started the discussion and provided the researcher with better insight into the participants' perceptions.

5.1.2 Question 2

*What is your perspective of the main **challenges** in South Africa associated with optimal/effective BIM implementation?*

This question aligned with the study's first objective, focusing on BIM implementation challenges. After reading the interview notes, the challenges were grouped according to five main themes: educational, cultural, legal, financial, and governmental. Most of these challenges overlap amongst the different themes. Therefore, the challenges should not be considered individually but rather part of a more extensive system with interactions and relationships. With this holistic perspective, the researcher aimed to describe the different challenges mentioned by the participants.

Educational:

Several participants implied that there is a general lack of awareness of BIM in the industry. For example, P2, P7 and P8 suggested that organisations do not adopt BIM because the business stakeholders still do not understand the benefits of BIM. P6 similarly noted that many professionals in the industry have a misinformed view of what BIM is and are unaware of the full extent of the benefits or value of BIM. From the responses, it was clear that especially construction companies in South Africa lack a mature understanding of BIM. Furthermore, P1, P4 and P9 specified that asset owners tremendously inhibit BIM adoption because they are not aware of the value of BIM. Ironically, asset owners should obtain the most value out of BIM, as indicated in Section 2.1.2. P4 confirmed that the most significant value of BIM lies in the operational phase and benefits the asset owner in the long term. However, P4 remarked that one of the reasons that asset owners are not using BIM is because BIM is being marketed as a design and coordination tool instead of an asset management tool.

In addition to the lack of BIM awareness, seven participants agreed there is a lack of BIM competency or BIM skills in the industry. Four participants explained that there are not many BIM experts in the industry, and there is not much being done in terms of education and training. P4 explained that BIM implementation requires "hard" and "soft" skills. The hard skills are technical and relatively easy to learn, but the soft skills involve BIM coordination,

collaboration, and management. P4 remarked that soft skills are critical for effective BIM implementation but are not being taught at universities. Furthermore, according to P4, there is confusion regarding which BIM capabilities are foundational skills taught at universities and industry skills taught in the industry.

Additionally, it was implied from the participants that it is almost impossible to acquire BIM capabilities in the industry without external training or education due to the shortage of BIM experts in the industry. P8 explained that senior professionals are typically not as digitally capable as younger individuals. Hence, younger individuals are often tasked with designing and managing digital information without having the required training. P8 reasoned that the younger individuals lack the experience of older generations, which creates a knowledge gap in the industry and inhibits effective BIM implementation. In conclusion, the consensus was that the industry lacks BIM competency, and the provided education and training at universities and the industry are not adequate.

Cultural:

According to the participants, a major cultural challenge in the industry is resistance to change. P8 explained that the construction industry had not experienced much change over the past few decades. People have grown accustomed to certain ways of producing, managing, and exchanging information and do not want to change their ways to a more digital approach. P1, P2, P3 and P8 viewed that the older generations are usually hesitant to change and adopt new processes or technologies. As highlighted by P2, the problem was that these older generations are the current business owners and decision-makers. Hence, their decisions reflect the decisions of the entire industry. The participants implied that businesses that do not keep up with industry trends would lose their competitive advantage.

Another challenge mentioned by many participants was the lack of collaboration between project stakeholders. The participants suggested that the great value of BIM is achieved by effective information exchange. Therefore, ineffective collaboration inhibits BIM implementation. P3 explained that project stakeholders practice “silo BIM”, where they use BIM internally within their organisations, but there is no collaboration element amongst different project stakeholders. Similarly, P2 highlighted organisations in South Africa are reluctant to share information. P4 remarked that this is due to the competitive culture in the industry; organisations only focus on their individual profits and not on the success of the project. The varying levels of BIM maturity amongst project stakeholders further contribute to the lack of collaboration, as P1, P3 and P4. Therefore, it is not only a cultural challenge but also an

educational challenge. Furthermore, P3 pointed out that organisations adopt different BIM software and standards, making it difficult to work collaboratively.

Legal:

The absence of formal BIM guidance on projects was viewed as another common challenge in South Africa. P1 and P4 claimed that BIM systems often fail on projects if there are no formal BIM requirements from the client. Formal guidance includes standards of information exchange, Employer's Information Requirements (EIR) and BIM Execution Plans (BEP) as explained by P1. P4 remarked that an absence of formal BIM requirements leads to the success of the BIM execution system being highly dependent on the success of the most mature authors within the project setting. In addition, BIM systems typically fail if the workload is not shared amongst the project team, according to P4. Four participants specifically mentioned that the absence of a national BIM standard is a significant barrier to BIM implementation in South Africa.

In addition, participants felt that traditional contracts and procurement methods do not support BIM implementation. P4 and P5 remarked that traditional construction contracts are limited and do not support integrated collaborative project delivery. P8 confirmed that the traditional procurement system is outdated. P8 explained that traditional projects are associated with information losses, and contractors are typically involved too late in the project. Therefore, P8 associated traditional procurement with waste. P4 had a similar opinion and added that traditional contracts do not address digital document management. Furthermore, P2 highlighted the legal barriers involving copyright and IP that are not addressed by traditional contracts. The participants suggested that no formal and legal guidance on projects is inhibiting BIM implementation.

Financial:

According to the participants, a huge reason for the slow rate of BIM uptake was the high implementation costs associated with BIM. For example, P5 stated that substantial capital investments are required for initially upskilling South African firms due to the lack of BIM experts in the industry. The direct and indirect costs were outlined by P7, namely, hardware, software licenses, network upgrades, upskilling and training. Furthermore, P3 implied that the highest BIM implementation costs are associated with the time lost due to decreased productivity while the organization is still learning. P3 explained about the time-learning curve where the benefit of BIM is only achieved over a long time once enough is learned. BIM was

perceived to be too risky for some organisations, as described by P1 and P5. However, P6, P8 and P9 argued that BIM should not be considered an additional cost but a cost reduction. P9 agreed that BIM implementation is expensive initially but explained that the costs are won back through better efficiency and productivity. Therefore, P8 argued that the high cost of BIM implementation is a misperception. Then again, P8 also remarked that BIM could be very expensive if the wrong processes are followed. Hence, P8 implied that it is an education challenge rather than a financial challenge.

Expensive software licenses was another challenge brought up by P4 and P7. P4 remarked that the available software packages do not match the South African market and industry needs. P4 and P7 expressed that software license costs are expensive and provide functionalities that are often irrelevant. P4 explained that the most sophisticated software licenses have much more functions than are needed, and affordable packages cannot perform the basic BIM processes. This challenge was perceived to prevent many firms, especially smaller firms, from adopting BIM. In contrast, P6 and P8 argued that software costs are not comparable with the cost reduction they produce. However, there seems to be a lack of supporting software that fulfils the needs of smaller South African firms.

Some challenges mentioned were associated with the third world characteristics of South Africa, including theft, vandalism, and poor network infrastructure. P7 explained that BIM promotes the use of expensive technological devices, including tablets, drones, and sensors. Firstly, many construction sites are in low-income areas. Secondly, the bulk of the South African construction workforce is hired on a non-permanent basis earning minimum wage. Therefore, according to P7, the risk of theft is significant and can lead to BIM implementation becoming very expensive. In addition, South Africa is prone to protests and vandalism, which could lead to damages.

Furthermore, P2 raised the point that there are still many rural sites in South Africa with poor or no internet connection. P2 implied that poor connection inhibits effective BIM processes such as coordination, collaboration, and communication. Therefore, the upgrading and expanding of network infrastructure will add to BIM implementation costs.

Governmental:

The government represents the largest client in the industry and play a role as educator, regulator, and policy maker. The participants remarked on the lack of effort from the government in driving or facilitating BIM. P6 and P9 were concerned about the government's

competency in leading the BIM initiative. Although the UK and USA governments led the BIM movement, P6 doubted that the South African government would follow the same route. P6 explained that these countries have the in-house capabilities to perform large amounts of work themselves, whereas most of the work in South Africa is subcontracted to private organisations.

Furthermore, P1 and P7 explained that the government is somewhat constrained to what they can do. They suggested that private organisations have more freedom to implement BIM and drive BIM from their side. Moreover, P1, P2, P6 and P7 addressed the resistance from the government in adopting new technology because of the perception that it might take away jobs. However, P6 explained that BIM will not take away jobs but will require new skillsets in the industry. Most of the participants agreed that BIM and digitalization would save money for the government in the long term, creating more jobs.

5.1.3 Question 3

*What **strategies** or **initiatives** do you think will promote effective BIM implementation (BIM at a high maturity)?*

This question aligns with the study's second objective, focusing on the solutions to BIM implementation. The purpose of this question was to explore possible strategies or initiatives while addressing the challenges identified in Question 2. Although the focus of this question was on solutions at an industry level, some strategies and initiatives applied at organizational and project levels were also discussed. The organizational solutions are first discussed, and the project solutions follow. After that, the industry level solutions are thoroughly discussed. These are divided into these themes: develop standards, update contracts, increase awareness, education and training, and government initiatives.

Organisational solutions:

The organizational solutions to BIM adoption and implementation were a common point of discussion. The majority of the participants suggested that AECO organisations thoroughly examine available technologies and consider adopting digital processes to improve their businesses. P6 explained that the benefits of BIM implementation are different for every project stakeholder. Therefore, every organisation should discover their own potential BIM benefits, according to P6.

P8 reasoned that it is the responsibility of construction industry professionals to keep up with industry trends and deliver the best service they can. These trends include using the best tools or systems available to them, such as BIM software and processes. Two participants, namely P6 and P8, suggested that the cost of technology be compared to the time and money saved through implementing digital processes. Furthermore, P2, P5 and P6 recommended that organisations adopt a clear strategy with specific end-goals. P6 suggested that each business develop its own “BEP” or “digital strategy” to improve its specific business operations.

Other participants similarly reasoned that AECO organisations have different objectives and need to adopt specific business strategies. For example, P6 suggested companies examine the ISO 19650 standard that includes a defined work list and requirements per job title to assist them in discovering their BIM role. In addition, P4 recommended that organisations focus on improving their operational effectiveness before improving their strategic competitiveness. P4 reasoned that those operational improvements generate direct cost savings and can be done with small steps. Whereas improving a business’ strategic competitiveness is a long-term goal that will not necessarily generate immediate benefits. Furthermore, P4 explained that it becomes easier to set strategic BIM goals, adopt IPD aspirations, and set performance targets once a high level of operational BIM maturity is reached.

In adopting a BIM strategy, P1, P2, P5 and P6, emphasized the importance of communicating the end-goals to everyone in the organisation. Furthermore, they recommended that clear guidelines or standards be developed to guide people to follow the new processes and workflows. The participants believed that change management and the restructuring of firms play a huge role when undergoing digital transformation. Some people in the industry, especially older people, might never become BIM competent, as alluded by some participants. Therefore, P9 stressed that older individuals should be strategically positioned where their knowledge and experience can still be used.

The participants suggested organisations start with small goals, such as moving away from paper and become fully digital. However, P8 remarked that moving away from paper is difficult because people have the habit of printing their work. The use of paper, according to P8, leads to outdated copies causing misinformation, which is a step backwards. Furthermore, P2 highlighted the direct cost savings on printing. In conclusion, the participants recommended that organisations develop goal-oriented strategies to increase their BIM maturity and capability in phases. Secondly, these strategies should be communicated to entire organisations to guarantee participation and buy-in from everyone.

A key recommendation for organizations in adopting BIM was to start with a pilot project. P1 and P3 encouraged the idea of pilot projects. Once there is a proof of concept, more buy-in will be gained, as remarked by P3. Furthermore, P3 explained that pilot projects could serve as a framework for developing best practice guidelines or standard approaches that guarantee effectiveness. Similarly, the importance of practical experience on real projects to learn and apply new skills was highlighted by P8. Moreover, P8 remarked that training courses are expensive and time-consuming and recommended that organisations pick a project and implement BIM on the project. Both P3 and P8 pointed out that learning BIM takes time, but P8 reasoned that a clear strategy with specific milestones or objectives would yield the benefits.

Project solutions:

BIM implementation on a project is a complex approach because many different organisations are working together. P1 and P6 suggested there be clear BIM goals and objectives from the onset of the project. They also mentioned that asset owners should be made aware of the value of BIM to enforce specific BIM deliverables. P1, P2, P3 and P6 emphasised the importance of formal documentation in describing the quality and quantity of information produced and how information is exchanged. As explained by P1, the BIM deliverables include a BEP, EIR and PIR, among other documentation. P1 further highlighted the importance of BIM deliverables in constructing as-built models to assist the asset owners in the operational phase. These formal BIM requirements or deliverables need to be managed. Therefore, P2 and P8 stressed the importance of a dedicated BIM coordinator ensuring that all project stakeholders carry out their respective BIM roles and responsibilities.

Furthermore, P2 remarked that a project should also have a dedicated data manager or information manager. The data manager should ensure that the correct quality and quality of information are produced according to the Level Of Information Need (LOIN) requirements. P3 indicated that these BIM requirements and roles are defined and explained in the ISO 19650 standards.

Increase awareness:

Many participants recommended that BIM awareness be increased in South Africa. P8, P1, P4, P5 and P9 remarked that it is vital that asset owners be convinced of the value of BIM through all phases of an asset's lifecycle, especially during the operational phase. P9 recommended convincing business owners of the value of BIM by providing them with well-

known studies and reports such as the “Business value of BIM for owners” (McGraw Hill Construction, 2014b). A suggestion from P1 was to visually show them what is being done by BIM mature organisations. This solution motivated the concept of strategic partnering raised by some participants, where firms partner up and learn from one another. The participants implied that if asset owners make BIM a requirement, many organisations will have to adopt BIM to maintain competitiveness.

On the other hand, P8 argued that architects, engineers, and contractors practice a professional service. It is their responsibility to keep up with industry trends to deliver the best service they can. Therefore, P8 and P6 suggested that organisations take a proactive approach in adopting BIM before being forced by clients. Whether the client, contractor or consultant should initiate BIM, it was evident from the participants that all organisations in the construction industry need to be made aware of the value of BIM. P8 motivated that if all organisations are made aware of the value of BIM, BIM uptake will increase rapidly.

In addition to raising awareness in the industry, P7 recommended that the public be made aware of BIM. For example, P7 suggested showing 3D models to the public through virtual reality rooms or headsets since this can excite the public about upcoming projects. This initiative promotes public participation, could generate helpful ideas and promotes transparency and accountability. P3 remarked that the BIM Community Africa is facilitating the needed BIM discussions. However, it was clear from the interviews that BIM awareness in South Africa is still shallow, and more discussions are needed to increase awareness in the entire industry.

Education and training:

The participants mentioned some valuable solutions to increase the BIM skills and competency in the industry. P1 highlighted the change in required skillsets introduced by BIM and digital transformation. P6 and P8 suggested that industry professionals need to be taught how to produce, manage and exchange digital information. They explained that these skills need to be taught to students and working professionals. The participants confirmed that university curricula need to include BIM processes and software use. Similar to P6 and P8, P4 recommended that students be taught the technical BIM skills and the process skills involving coordination, collaboration and communication. P2 proposed the development of a national education or upskilling program. P2 also proposed an initiative to allocate a fraction of a projects’ profit margins toward the training and upskilling of workers in BIM and digital

processes. P2 and P1 recommended that such initiatives should form part of job creation and skills development initiatives.

Develop standards:

Four participants expressed the importance of developing BIM standards to facilitate BIM implementation in the industry. As highlighted by P4, firms need guidance, especially when they are still learning new processes. P4 explained that standards are approaches or best practices that guarantee effectiveness. Therefore, P4 motivated firms that spend money on BIM implementation should be encouraged to adopt a rigid BIM standard since it provides more certainty of a positive return. The majority of participants referred to the ISO 19650 standard as the globally recognized BIM standard. The recommendation from some participants was that South Africa adopt the ISO 19650 standard and include a national annex to meet local requirements. P5 remarked that national BIM standards would ensure a more substantial roll-out of BIM systems on projects in South Africa.

Update contracts and procurement:

In addition to BIM standards, participants recommended that changes be made to the traditional contracts in the industry. P5 recommended that contracts be modified to accommodate BIM systems and processes better. The perception from some participants was that current contracts do not address project stakeholder liability and responsibility regarding BIM models. Furthermore, P8 suggested changing the contracts and the entire procurement approach to more collaborative agreements, such as an IPD. P8 explained that an IPD project involves a multi-party contract where the project risks and rewards are shared. The risk-sharing approach, according to P8, encourages project stakeholders to work collaboratively for the benefit of the project, rather than only for their individual gain. P8 expressed that clients be made aware of IPD and the better value for money generated through this type of procurement. Contracts focusing on BIM processes could mitigate the challenges associated with legal barriers and the lack of collaboration on projects.

Government initiatives:

Government initiatives was another common topic of discussion. Some participants reasoned that the global construction industry has realized the value of BIM and reasoned that the South African government should also be made aware of the economic value of BIM. P8 recommended that the government learn from other countries and apply their BIM initiatives

and adoption strategies locally. However, some participants argued that South Africa is very different and need to develop their own strategy. The development of digital cities and smart cities was encouraged by P1, P4 and P5. P5 recommended that the government start collecting digital data of their assets, even if they do not yet know how to use the data.

Furthermore, P5 suggested that municipalities and building controls enforce building plan submissions in BIM models instead of paper hard copies. Similarly, P6 suggested that the government mandate BIM on public projects, encouraging companies to adopt BIM. However, since the transition to BIM requires new skillsets and job roles, some participants were concerned if the industry is ready for a BIM mandate. Therefore, P1 argued that the first step is to upskill the industry. P1 recommended that the government engage with educational institutions to discuss the competency of professional graduates to fulfil their roles in the changing industry.

Furthermore, P1 suggested the government develop a BIM implementation framework including hard and soft BIM mandates, BIM standards, and education and training incentives. Another recommendation regarding the upskilling of working professionals, proposed by P1 and P2, was that the government develop subsidies to promote BIM education. However, both P1 and P2 argued that the funding source should be carefully decided on and that the incentives should contribute to the countries' job creation and skills development goals. Addressing the challenge mentioned that the government is afraid to adopt technology because it takes away jobs; the participants argued that BIM would save money and generate more funding for more projects, creating more jobs.

5.1.4 Question 4

*Who (people or institutions) do you think are responsible for **drive/facilitate/promote** BIM implementation? What are their roles?*

This question aligns with the third objective of the study, and its purpose was to identify the people or institutions responsible for leading or facilitating BIM adoption and implementation. The researcher remarked some opposing arguments about who should lead or drive BIM implementation in the industry. The confusion was whether BIM implementation should take a top-down or bottom-up approach. A top-down approach meant that the government takes leadership at an industry level, and a bottom-up approach meant the private sector takes leadership. Clients are "top" at a project level, and the other project stakeholders are "bottom". At an organizational level, business owners and decision-makers are "top" and lower-ranked

individuals, “bottom”. Thus, the discussions for this question were divided according to organizational, project and industry levels.

Organisational level:

At an organizational level, P2, P3 and P8 emphasized the importance of business owners and senior management buy-in to the BIM implementation process. BIM implementation will fail without leadership, according to P8. The participants claimed that BIM implementation needs to take a top-down approach in organisations and should be driven by the decision-makers. However, P3 recommended that organisations also need a BIM champion to drive the technical side of BIM. P2 and P8 recommended that older generations be open to new ideas and embrace the technical capabilities of younger individuals. P8 mentioned a different type of driver. P8 explained that organisations should discover the advantages of BIM since this will be the driving force that motivates everyone in the firm.

Project level:

In a typical project, the main stakeholders include clients, contractors, and designers (engineers, architects and other consultants). There is often confusion about which party should lead BIM implementation on a project. However, the participants clarified the confusion. P1 argued that the designers often initiate BIM but argued this approach is unstructured and often fails. Therefore, P1, P3 and P5 recommended that clients initiate and drive BIM by providing specific BIM requirements (EIR and PIR). The argument provided by P5 also carried some weight. P5 remarked that designers and contractors are typically involved with an asset for a few months, while asset owners could own the asset for decades. However, P5 explained that while the client should give the formal BIM requirements or guidance, the BIM responsibilities should fall on the designer or contractor, depending on who is more capable. P8 argued that designers and contractors practice a professional service and should be capable of executing the BIM process. Considering the abovementioned discussions, it became evident that there cannot be a single driver and that all parties have an essential role in BIM implementation. The client or asset owner’s role was perceived to set the standard for BIM requirements and deliverables. However, contractors and designers need to be capable to deliver these requirements.

Industry level:

The industry is a much more complex environment than projects. There is a private sector and a public sector with many different organisations and institutions playing a role in the industry. P8 emphasized the importance of leadership in the industry to drive BIM adoption. However, there is confusion about whether BIM leadership should come from the public or private sector. P4, P6, P8 and P9 felt that the initial drive should come from the private sector. P4 suggested that the private sector set the standard for BIM while pushing the public sector to follow its lead by developing regulations, mandates, and policies to facilitate BIM implementation. P4 explained that the private sector relies on profits and is more driven toward performance than the public sector. Hence, the private sector was expected to be the early adopters. P9 also believes that South Africa's expertise is mainly located in the private sector, and they should lead the initiative. These participants seemed to question the competency of the South African government in driving BIM adoption.

P2 remarked that the industry is on the right track, with the South African BIM Institute leading the BIM initiative. In contrast, P3 seemed concerned that the current drive is from the BIM Institute and software vendors since these entities are profit-driven. Therefore, P3 suggested that government spheres start driving BIM by raising awareness and educating people. Similarly, P1, P5 and P6 recognized the impact of the government as an educator, regulator, policymaker, and largest asset owner in the industry. However, P1 and P7 remarked that the public sector is somewhat constrained to what it can do. P7 explained that the private sector has more freedom to drive BIM from their side. The conclusion was that BIM implementation requires a joint effort between the public and private sectors, including all industry institutions.

5.1.5 Question 5

*What do you think are the **best practices** to follow when adopting and implementing BIM? What are the worst practices to follow?*

The purpose of Question 5 was to pinpoint the best and worst practices regarding organisational, project and industry BIM implementation.

Organisational level:

The interview responses' three main themes were strategy, change management, and pilot projects at the organisational level. The participants reiterated some of the points mentioned

in Question 3, such as the importance of a change management strategy with clear objectives aligning with the business goals. In addition, the importance of communication, people management and strategic firm restructuring were all recommended best practices. Furthermore, some participants advised that organisations refrain from transforming the business too quickly. The participants recognized that BIM implementation is a significant change and, therefore, small steps need to be taken to increase the organization's BIM capability and maturity. P4 recommended that organisations have at least two full-time BIM champions to drive BIM implementation, one at a senior level and one at a junior level. Another best practice mentioned by P3 was strategic partnering with BIM mature firms. Many participants also reiterated the importance of pilot projects as a best practice to learn BIM within an organisation.

P8 described a worst practice at the organizational level. "Pseudo-BIM", according to P8, is when organisations use traditional methods to produce project information and develop a BIM model based on this information. P8 argued that this leads to BIM being added to the traditional approach, reducing work. P8 explained that the BIM model should be constructed first, and all project information, including geometric and non-geometric data, should be generated from this central data point or BIM model.

Project level:

Most participants indicated that a best practice on a project level is a clearly defined BEP, describing project stakeholders' BIM roles and responsibilities, including BIM processes and workflows. P5 suggested a standard like the ISO standards be used as guidance. Furthermore, the participants noted that these processes be strictly enforced. P1 and P7 reiterated the importance of data management. P7 recommended there be a hierarchy in place to dictate the BIM roles, responsibilities, and workflows. The setup of a BIM user forum was a best practice encouraged by P6. P6 explained that the forum is a communication channel where open discussions are conducted with the project team.

P8 mentioned three best practices for BIM implementation at a project level:

- All project stakeholders should recognize the advantages of BIM and digitalization.
- Involve the contractor early in the design stage to ensure constructability and early identification of errors.
- The digital model program should run ahead of the physical construction program to achieve the "proactive" benefits of BIM and reduce changes later in the project.

In terms of worst practices, P3, P6 and P7 mentioned a similar phenomenon. “Silo BIM” is the term referred to by P3, which entails organisations working on the same project using different BIM models. As explained by P6, if BIM is not implemented collaboratively among project stakeholders, many benefits are lost. P7 added that having multiple models on a project creates uncertainty and can lead to incorrect information being shared.

Industry level:

A best practice to promote BIM adoption in the industry, according to P3, was to develop a national BIM standard. P2 was convinced that well-documented case studies would be the best solution to increase BIM uptake. Explaining further, P2 reasoned that South Africa needs a proof of concept to show the possible benefits of BIM. The overall perception from most participants was that there is no single best practice that can be applied at an industry level. It seemed to be a much more complex approach, involving different organisations with interlinked relationships. However, some possible solutions that could be included in a best approach were mentioned under Question 3 and Question 10.

5.1.6 Question 6

*What kind of **assistance** do organisations need to effectively implement BIM in terms of technology, people and policies? (Or undergo digital transformation)*

Question 6 builds onto the discussion from question 5. Once the best practices were identified, the researcher deemed it essential to ask the participants what assistance firms would need to adopt and implement BIM effectively. The discussions revolved mainly around technical BIM support, guidance in BIM processes, and digital transformation. As explained by P3 and P6, firms require initial guidance in developing a BIM strategy, choosing the right technology platform, and developing standard BIM workflows and policies. P2 similarly emphasized the importance of third-party assistance in developing BIM processes that align with business objectives. P2 suggested firms approach BIM experts, software developers or partner organisations to assist change management.

Furthermore, P2 and P5 pointed out the technical support required around software modelling, especially when organisations are still in the learning phase. P7 noted the assistance needed regarding BIM training. However, P7 argued that available online training material is abundant. The participants implied that there is an opportunity for organisations wanting to provide BIM services such as BIM consulting, BIM modelling and BIM training.

5.1.7 Question 7

*In your opinion, how can we quantify the **benefits** of BIM? (Consider all project stakeholders)*

Question 7 addressed one of the considerable challenges that seemed to keep organisations from adopting BIM - the high implementation costs and uncertainty in returns. This question aimed at quantifying the benefits of BIM to convince firms to adopt and implement BIM. The participants recognized the difficulty in quantifying the value of BIM. P2, P4 and P7 recommended that case studies with and without BIM be compared with one another. P7 suggested that the difference in project rework and the number of change orders will likely reveal the benefits of BIM.

In comparison, P2 recommended that the time taken in a traditional workflow should be compared with a BIM workflow. P4 explained that a value could be calculated for RFI's, and a coordination cost can be calculated depending on the amount of RFIs. P6 explained a more holistic approach to quantifying the benefits of BIM. P6 remarked that each business is different and needs to identify how BIM could improve its time, cost, and quality. P6 suggested that each organisation assess their operational costs and discover how BIM can reduce them. An example of P6's method is explained as a recommendation for a construction company in Question 8's discussion in Section 5.1.8. Although the methods proposed by the participants provided some form of quantification, it seemed that an exact quantification of the benefits of BIM is almost impossible. However, most participants believed that BIM yields a positive ROI in the long term.

5.1.8 Question 8

*Do you have specific **recommendations** for project stakeholders to start adopting BIM or move up the BIM maturity ladder?*

Question 8 forms part of the study's fourth objective, to provide recommendations or guidance to different organisation types. This question enabled the participants to address specific organisation types that might have been overlooked in the previous questions. Although some recommendations were still quite broad, the participants mentioned specific recommendations relative to specific organization types. The main organization types mentioned in the interviews

were architects, asset owners, consultants, contractors, project managers, subcontractors, and suppliers.

The following recommendations were gathered for these project stakeholders:

a. Architects.

The participants implied that architectural firms are the current frontrunners regarding BIM capabilities since they have been designing in 3D environments for many years. Hence, little advice from the participants was explicitly aimed at architects. However, from the discussion with P7, it was implied that architects have acquired the modelling side of BIM but have yet to reach a BIM management or coordination maturity. Therefore, P3 recommended that architectural firms set up a BIM implementation plan for each new project to guide the information management process and establish the required BIM deliverables.

b. Asset owners (clients).

P3, P5, P6 and P7 encouraged asset owners to become aware of the value of BIM. P6 noted the savings they can get on fewer rework costs since BIM allows them to make informed changes before construction commences. Furthermore, P5 elaborated on the asset management benefits of BIM. P5 suggested asset owners start requiring BIM deliverables as part of project delivery. Similarly, P3 recommended that asset owners enforce BIM with formal documentation and start collecting BIM data. P1 remarked that asset owners become aware of the Organisational Information Requirements (OIR), the Asset Information Requirements (AIR), the Project Information Requirements (PIR) and the Exchange Information Requirements (EIR), as described in the ISO 19650 standards. P5 emphasised that BIM data could improve these organisations' asset management processes such as financing, operations, preventative maintenance, future planning, renovations, utilities, and functionalities. Furthermore, P5 suggested asset owners start looking at BIM models as part of digital cities that could develop into smart cities. P3 also recommended that asset owners research Computerized Maintenance Management System (CMMS) and Computer Aided Facility Management (CAFM) applications to use the information at handover.

c. Other Consultants.

P6 remarked that consulting companies might not be able to reduce their operational costs with BIM significantly, but they have the opportunity to increase their quality of work. Accordingly, P6 suggested that consulting companies consider delivering BIM services such as BIM consulting, coordination or management, digital twin development, or green building services. P9 similarly implied that consulting companies consider offering these BIM services and added that they offer BIM modelling as a service.

d. Contractors.

P3 recommended contractors hire BIM managers/coordinators to help drive the internal workflows to use project information for their benefit. P9 claimed that construction companies in Australia and New Zealand already have their own BIM modellers and managers. They see the benefit that BIM brings for the business and use BIM regardless of the client's requirements. P3 and P9 recommended that South African construction firms should follow the same route. P6 motivated contractors should think of BIM as a cost reduction rather than cost addition. P6 gave an example of how a construction company could approach BIM adoption. Suppose their highest costs are (1) manhours, (2) equipment and machinery not being used, (3) materials arriving early or late, and (4) accidents. P6 suggested the company determine:

1. How many manhours could be saved through more efficient tasks such as calculating quantities, creating schedules and fewer RFIs?
2. How much money could be saved using BIM through better site planning and resource optimization to limit equipment and machinery not being used (rent costs, depreciation, storage space)?
3. What are the cost implications of storing materials, and how could this be reduced using BIM?
4. What are the costs of accidents, and how can this be reduced using BIM? Consider improvements to processes such as planning, coordination, communication.

Once these questions are answered, P6 reasoned that the benefits could be realised, driving BIM implementation in the organisation.

e. *Project managers.*

It can be implied that project managers play a prominent role in BIM management. Therefore, they are responsible for becoming BIM competent and facilitating the BIM process on projects, as emphasized by P3. There were no other specific recommendations to project managers. However, since they often represent clients, contractors, or consultants, they could also benefit from the recommendations given to these companies.

f. *Subcontractors and suppliers*

The interviews suggested that the subcontractors and suppliers become aware of BIM and consider how BIM could benefit their business. For example, P3 recommended that subcontractors acquire BIM software to develop fabrication models, and suppliers could digitize their product data on BIM libraries.

The main consensus regarding the different project stakeholders' approaches to BIM implementation was that each organization should become fully aware of BIM and the potential benefits that it may have. Furthermore, no single approach applies to all organisations, but BIM implementation is a specific process that should align with specific organizational goals and objectives.

5.1.9 Question 9

*What do you think are the **roles** of the following institutions in promoting/accelerating/facilitating optimal, industry-wide BIM implementation?*

The focus of Question 9 is on the role of the public sector regarding BIM implementation. The responses were divided into the different forms of government representation: the government as asset owner, regulator, policymaker, professional bodies, and educator. The last point of discussion is on software developers. Although they are not a public entity, they play an essential role in BIM implementation.

- a. *Government as an asset owner.* The majority of the participants highlighted the importance of the government facilitating BIM adoption and implementation. P5 and P7 motivated the government to become aware of BIM and the value of digital twins for asset management. P5 spoke about developing smart cities and encouraged the government to collect digital

data about the built environment. Furthermore, P1, P3 and P6 suggested the government mandate BIM by enforcing certain BIM requirements on projects. P3 noted that once BIM is mandated, the industry will also adopt BIM. However, P1 recommended that the government assist firms by developing BIM standards, raising awareness, and educating the industry. P1 suggested the government should provide incentives to promote BIM education such as BIM workshops, BIM seminars or subsidies on public projects towards technology adoption and upskilling the workforce. P1 strongly believed the government should take the lead in BIM implementation and set the standard for the industry to follow.

- b. *Regulator.* P3 suggested that regulatory bodies develop a framework for a BIM mandate to give the industry direction.
- c. *Policymakers.* According to P3, policymakers should define minimum BIM requirements for projects and enforce them. P6 recommended that the ISO 19650 standards be adapted to the South African context since this was done by Spain, Germany, and Ethiopia, among others.
- d. *Professional bodies.* P3 suggested that these bodies drive BIM through creating awareness and doing BIM case studies. P6 recommended that they educate the industry on how to improve their processes.
- e. *Educator.* P1 and P2, P3, P4 and P6 suggested that educational institutions in the built environment update their curriculums to fulfil the new roles required in the industry. They identified the importance of teaching students BIM processes such as BIM modelling, coordination, collaboration, and management. P6 was more specific in stating that students be taught about the ISO 19650 standard that explains these BIM processes. Furthermore, P6 remarked that there is plenty of room for research on the impact of BIM in South Africa and recommended more research be done in this area.
- f. *Software developers.* P3 noted that software developers are currently driving BIM adoption and implementation in the industry. It seemed that software developers are currently setting the standard for BIM in South Africa. P3 recommended it should be the other way around where the industry drives BIM and software developers to provide solutions that suit the industry's specific needs. P4 similarly suggested that software developers should develop software packages that match the South African context. P4 highlighted that the current software is aimed at large organisations and has many complex or unnecessary functionalities. However, the SACI consists of many smaller firms, as implied by P4. P4

recommended that software packages be made affordable for smaller organisations and must be able to perform the basic BIM functions/processes.

5.1.10 Question 10

*What, in your opinion, would be the best **approach** to facilitate or accelerate effective and widespread BIM adoption in South Africa?*

After discussing various themes and topics, this question aimed at obtaining a final recommendation from the participants. Although some of these answers have been discussed previously, the single solution or best approach is highlighted here.

P8 remarked that the best approach would be recognising the problem and asking the correct questions before rushing to solutions. Similarly, P7 suggested that the challenges need to be addressed before finding a solution. Therefore, some participants, such as P1, emphasized the need for BIM discussions to address these problems. P8 explained that this process was followed in Ireland and described the four focus areas of Ireland's digital roadmap. P8 suggested South Africa follow a similar route and ask the following questions related to the four key themes:

1. Leadership: How will the companies in South Africa be leaded and who will lead them? How does the industry's demographics look? What are the different organisation types and sizes, and what are their roles?
2. Standards: What standards have these companies developed? How do we get them to use the same standard?
3. Education and training: How do we address the knowledge gap between people and organisations on construction projects?
4. Procurement: Are we using the best procurement method, or are there better methods that we can use?

The other participants also addressed some of the points mentioned by P8. For example, in addressing leadership, P1, P2 and P5 recommended that the best approach would be if the government takes leadership since they represent the country's largest clients. P5 motivated that the government should initiate a plan to develop digital cities. The data for digital cities, including buildings and civil works, can already be collected by municipalities, as suggested by P5. P5 recommended that building plan submittals be required in the form of BIM models rather than paper hardcopies. P1 and P5 implied that once BIM is a requirement on public

projects, uptake will increase rapidly. P2 highlighted another government approach entailing government incentives. P2 explained that BIM promotion incentives would create a demand for educational institutions to provide competent BIM professionals. Although the participants recognized the importance of government leadership, the participants agreed that BIM implementation is still a joint effort between all industry stakeholders.

P4 recommended that the education challenge be addressed. P4 motivated educational institutions should teach students how to create BIM models and coordinate, collaborate and manage information in a BIM environment. Another approach highlighted by P4 was aimed at software developers. P4 expressed that BIM uptake will increase rapidly if more affordable software packages are made available to perform the basic BIM processes required by the South African market and industry.

5.1.11 Question 11

*Any final thoughts on the **future** of BIM and digital transformation in South Africa?*

Question 11 was the final question, and its purpose was to gain insight into the participants' perception of the future of BIM in the construction industry. All participants recognised that the industry is changing and becoming more digital. Some participants strongly believed that the government would start mandating BIM within the next decade. P9 suggested that companies that do not implement BIM will lose their competitiveness. Moreover, P1 remarked that BIM might not be the only change expected for the future. Therefore, companies need to be prepared for future changes and adapt accordingly to remain competitive.

5.2 Data analysis conclusion

The interviews were analysed, and the participants' responses were discussed. These analyses are used to compile the interview findings in Chapter 6. The interview findings are followed by a further discussion where it is compared with the literature.

6 Findings and discussion

In this chapter, the interview findings are summarised and discussed according to the study's four objectives. Each section starts with a description of the objective, followed by a table summarising the main interview findings. Then, for each objective, the interview findings are compared with the literature in the form of a discussion. Georgiadou (2019) also used this method as a means of validation and called it a cross-comparison. Finally, the chapter ends with Section 6.5, where the researcher's proposal is developed.

6.1 Objective 1

Gain an understanding of the challenges associated with BIM implementation across the SACI.

P7 and P8 confirmed that the problems should first be identified before solutions are sought. This objective aimed to do what P7 and P8 suggested, to identify the challenges to BIM implementation in South Africa. The interview findings are summarised in Table 7, followed by a discussion of the interview findings compared with the literature.

6.1.1 Summary of interview findings (Objective 1)

The data used to populate the interview findings were mainly based on the interview discussions regarding Question 2 from the interview guide. The thematic analysis process proposed by Braun & Clarke (2006) was used to identify logical themes to group the challenges. The main themes for grouping the challenges were educational, cultural, legal, financial and governmental. Although they are grouped into separate themes, these challenges should be seen as part of a more extensive system with interlinking relationships. For each challenge, the participant that remarked or implied the challenge was referenced in Table 7. These statements were not directly quoted from the interviews but interpreted from the interview response analysis in Section 5.1.

Table 7: Challenges of BIM implementation in South Africa

Educational <ul style="list-style-type: none"> • Lack of BIM education and training (the majority of participants). • Lack of BIM competency (the majority of participants). • Lack of BIM awareness, especially asset owners and contractors (P1, P3, P4, P5 and P6). • Misinformation about BIM (P2, P6, P7 and P8).
Cultural <ul style="list-style-type: none"> • Resistance to change (P1, P2, P3 and P8). • Lack of collaboration (P2, P3, P4, P5 and P8). • Competitive nature (P2 and P4). • Varying levels of BIM maturity (P3, P4 and P5).
Legal <ul style="list-style-type: none"> • No formal guidance from clients (P1 and P4). • No industry standards (the majority of participants). • Outdated contracts, not addressing copyright and IP (P4 and P5). • Ineffective traditional procurement system (P8).
Financial <ul style="list-style-type: none"> • High implementation costs (P1, P5 and P7). • Upskilling takes time (P3). • Expensive software does not match market and industry needs (P4). • Theft and vandalism risk (P7). • Network connection infrastructure costs (P2, P7).
Governmental <ul style="list-style-type: none"> • No BIM mandates, standards, policies or incentives (P1). • Lack of competency (P6 and P9). • Technology adoption contradicts job creation initiatives (P1, P2, P6 and P7).

6.1.2 Discussion

Educational:

The concern regarding the lack of BIM education and training in South Africa, noted by the majority of the participants, was confirmed by several other researchers (Chimhundu, 2015; Kekana *et al.*, 2015; Meno, 2020; Moodley *et al.*, 2016; Pillay *et al.*, 2018; Tabesh, 2015). The

lack of BIM competency in the industry aligned with the education and training challenge and was specifically identified by Moodley *et al.* (2016), Pillay *et al.* (2018) and Tabesh (2015). These studies found that the education and training in South Africa do not produce graduates with competencies to deliver BIM projects. P1 and P4 confirmed that the graduates lack BIM skills. The mismatch between skills supply and demand is also one of the known challenges faced by the industry (Windapo & Cattell, 2013).

Furthermore, the participants emphasised the general lack of BIM awareness, which was reinforced by the literature (Chimhundu, 2015; Froise, 2014; Govender, 2018). P4 mentioned that BIM is used mainly by designers. Similarly, Govender (2018) highlighted the low BIM awareness among contractors and asset owners. The participants specifically emphasised the need to raise awareness to contractors and asset owners in South Africa.

Related to the lack of BIM awareness, P6 mentioned that industry professionals have a misinformed view of BIM, preventing them from adopting BIM. P6's perception was reflected by Meno (2020). Meno (2020) confirmed a lack of understanding of innovative technology in South Africa due to insubstantial research and development in the construction industry. Similar to P6, Meno (2020) explained that the lack of research prevents people from investing in innovative technologies. Furthermore, Govender (2018) highlighted that industry institutions responsible for informing and guiding the industry do not publish sufficient information regarding BIM.

Cultural:

The resistance to change was a common challenge to BIM implementation identified by P1, P2, P3 and P8, and was reinforced by local and international research (Akintola *et al.*, 2017; Chimhundu, 2015; Froise, 2014; Khosrowshahi & Arayici, 2012). For example, Meno (2020) expressed that people in South Africa perceive digitalisation as a disruption instead of a benefit. Similarly, P8 explained that professionals are used to a particular way of doing things. Thus, they do not want to change.

The lack of collaboration was a significant theme from the interviews and the literature. P3 explained that "silo BIM" is a problem where organisations perform BIM in individual silos but do not collaborate. Ogwueleka & Ikediashi (2017) supported P3 by noting that project stakeholders in South Africa work independently without using the collaboration benefit of BIM. Similarly, Froise (2014) remarked that the silo mentality in South Africa inhibits BIM implementation. As Froise (2014) pointed out and indicated by P2 and P4, the industry has a

fragmented culture. P3 noted that organisations are reluctant to share information and P4 remarked that is due to the competitive culture in South Africa. The competitive culture and lack of collaboration is a common challenge in South Africa identified by Kwofie *et al.* (2017) and Matsane & Aigbavboa (2015).

This fragmented culture in the industry leads to varying levels of BIM maturity, as expressed by P3. P3 and Akintola *et al.* (2017) explained that organisations adopt different standards and software, making it difficult to work collaboratively. Furthermore, large amounts of work are subcontracted in South Africa, according to Hlahla (2013), which further complicates BIM implementation.

Legal:

P1 and P4 indicated that the lack of formal BIM guidance on projects was a challenge. Similarly, Froise (2014) identified the lack of a legal framework regarding BIM implementation as a severe barrier. Furthermore, many participants noted that the lack of national BIM standards prevents BIM adoption, which was confirmed by Akintola *et al.* (2017).

P8 raised the point that the traditional procurement system is outdated, confirmed by Froise (2014) and Govender (2018). Govender (2018) explained that the traditional procurement system in South Africa results in silos among project stakeholders. For example, designers and contractors often do not share information, leading to duplication of work, change orders, time and cost overruns, and disputes (Govender, 2018).

Financial:

The high costs associated with BIM implementation was identified as a problem in South Africa by literature (Chimhundu, 2015; Kiprotich, 2014; Meno, 2020) and confirmed by P5 and P7. Similar to Meno (2020), P5 and P7 remarked that organisations see BIM implementation as risky. Similar to research (Becerik-Gerber & Kensek, 2010; Elmualim & Gilder, 2014), P3 explained that the largest expense of BIM implementation is associated with the upskilling and training costs. Furthermore, Kiprotich (2014) stated that smaller firms do not adopt BIM since they find training and software license costs very expensive. P4 confirmed that software licence costs are expensive and elaborated that they do not match the industry needs. Since most construction firms in South Africa are small and medium-sized firms (Table 5), P4 has a good point. However, P6 and P8 argued that software licence costs are insignificant due to the value that BIM brings to an organisation. The financial challenges that were not mentioned by

research but remarked by P2 and P7 included the risk of theft and vandalism and the high costs to upgrade network connection infrastructure.

Governmental:

The participants highlighted the lack of government drive in developing BIM standards, policies, and incentives, which was reinforced by research. Since 57% of construction projects in South Africa are publicly funded (Construction Industry Development Board, 2021) and the industry is heavily regulated by public bodies (Anthony, 2017), the government has a significant impact on BIM implementation. The importance of government policies and regulations were confirmed as critical drivers of uniform BIM implementation (Gu & London, 2010; Porwal & Hewage, 2013). Similarly, other studies found that a lack of government support and regulations stall BIM adoption (Migilinskas *et al.*, 2013; Wong *et al.*, 2011). The research participants agreed with the research, especially P1, emphasising government involvement as a critical factor to BIM implementation. However, P6 and P9 questioned the competency of the government in driving BIM implementation. One of the general industry challenges identified by Windapo & Cattell (2013) also included the government's capacity.

Another challenge related to the government was mentioned by P1, P2, P6 and P7, and it was the perception that technology adoption contradicts job creation initiatives. Similarly, Hlahla (2013) and Meno (2020) remarked that South Africans are threatened that technology will take away jobs. However, P6 explained that BIM should generate savings, creating more jobs. Therefore, this challenge could also be viewed as an educational challenge.

6.2 Objective 2

Identify possible solutions in terms of initiatives and strategies to facilitate and promote BIM implementation across the SACI.

The findings for objective two are mainly based on the interview responses to Question 3. However, the discussions from Questions 5, 9 and 10 also provided valuable information to portray a holistic picture of the possible solutions to BIM implementation. The identified strategies and initiatives obtained from the interview responses are summarised in Table 8 according to seven identified themes. These themes included raising awareness, education and training, promoting pilot projects, developing standards, updating procurement systems, developing software that meets South African needs, and government initiatives. The themes were identified using the thematic analysis method proposed by Braun & Clarke (2006).

However, the process was slightly simplified since a large part of the thematic analysis was already done in Section 5.1. These strategies and initiatives were proposed by the participants and forms part of the final proposal.

6.2.1 Summary of interview findings (Objective 2)

The summary of the interview findings according to Objective 2 is shown in Table 8.

Table 8: BIM implementation strategies and initiatives

<p>Raising awareness</p> <ul style="list-style-type: none"> • Make the government aware of the economic value of BIM (P4 and P5). • Convince specifically asset owners and contractors of the value of BIM (P1, P2, P3, P4, P5, P6 and P9). For example, through case studies (P2), strategic partnering (P3) and conducting more research (P6). • Initiate BIM discussions with the private sector, public sector, and educational institutions (P1). • Raise awareness and educate the industry through BIM seminars and workshops (P1). • Engage with the public to raise awareness and promote public participation through BIM (P7).
<p>Education and training</p> <ul style="list-style-type: none"> • Develop a national upskilling program (P2) and train professionals to produce, manage and exchange digital information (P6 and P8). • Research the impact of BIM in South Africa (P6), including newly required skillsets and professions (P1). • University curricula could include technical BIM skills and processes, including collaboration, coordination, and communication (P1, P2, P3, P4, P6 and P8). Teach the ISO 19650 standard (P6). • Promote knowledge sharing initiatives where people across all fields of the industry could learn from one another (P1). • Promote strategic partnering between organisations where they learn from one another (P3). • BIM education and upskilling incentives on projects as part of a project's profit margin (P2).

Promoting pilot projects

- Well documented pilot projects could provide proof of concept and show the benefits of BIM (P2 and P3).
- Best practice standards could be developed using well-documented pilot projects (P3).

Developing standards

- Guide firms on BIM practices that guarantee effectiveness (P4).
- Introduce common national standards of information exchange and the use of software to eliminate confusion in the industry (P3, P6 and P8).
- Adopt ISO 19650 as an industry standard and include a national annex to meet the South African requirements (P6).

Updating procurement systems

- Update construction contracts to accommodate BIM systems and processes (P5).
- Construction contracts could address IP and copyright concerns (P7).
- Consider more collaborative procurement methods such as IPD (P8).

Developing software that meets South African needs

- Software suppliers could develop BIM software that suits the specific South African market and industry needs (P3 and P4).
- Consider more affordable software packages that can perform basic BIM processes, suitable for smaller organisations in South Africa (P4).

Government initiatives

- Learn from other countries and use their BIM implementation methods to build a BIM implementation strategy in South Africa (P8).
- Develop a BIM implementation framework with hard and soft BIM mandates to give the industry direction (P1 and P3).
- Engage with educational institutions and the industry to discuss the newly required job roles and skillsets (P1).
- Develop government subsidies to promote BIM adoption and upskilling in the industry (P1 and P2).
- Start collecting data to develop digital and smart cities (P1, P4 and P5).
- Enforce building plan submissions in BIM models rather than paper hardcopies (P5).

6.2.2 Discussion

Raising awareness:

Raising awareness was implied to be the first step to increase BIM uptake and acceptance across the industry. P1 raised the point to initiate discussions between the private, public, and educational institutions. Similarly, Chimhundu (2015) and Mtya (2019) agreed that industry stakeholders should collaborate and discuss solutions for BIM implementation. The majority of participants stated that asset owners and contractors need to be convinced about the value of BIM. Similarly, Kiprotich (2014) stated that more investments toward BIM would be seen once the industry becomes aware of BIM. Froise (2014) further encouraged contractors and all organisations in the supply chain to become aware of BIM. P1 and Chimhundu (2015) both recommended that BIM awareness could be raised through seminars and workshops. P7 made an interesting suggestion regarding raising awareness. P7 suggested that the public be involved with 3D BIM models and virtual reality to excite the public, raise awareness and promote public participation.

Education and training:

P2 specifically mentioned the development of a national upskilling program regarding BIM. Furthermore, P6 and P8 remarked that industry professionals need to become more digitally competent to produce, manage and exchange digital information. Similarly, Moodley *et al.* (2016) also recommended that the industry needs a national education and training program to increase BIM competency. P2 recommended that there be BIM upskilling incentives as part of the project profit margin to educate and upskill the workforce. Furthermore, the lack of skills is a general challenge in the industry (Pillay & Mafini, 2017), and promoting education and training, in general, could increase the industry's growth.

Furthermore, P6 pointed out that more research is needed on the impact of BIM implementation in South Africa. Chimhundu (2015) and Mtya (2019) confirm the need for continuous research on BIM. Mtya (2019) explains that research could help update BIM guidelines as technology develops and BIM maturity rates increase. Furthermore, P1 mentions that research is needed on the required skillsets and professions in the SACI. Research on these required skillsets could address the mismatch between required skillsets and available skillsets, as Windapo & Cattell (2013) also identified.

Most participants urged that university curricula incorporate technical BIM skills and additional BIM coordination and management skills. P6 noted that the ISO 19650 standards could be taught to explain the BIM processes and project roles. Several studies have found the need for BIM skills to be taught at universities (Moodley *et al.*, 2016; Pillay *et al.*, 2018; Tabesh, 2015). Meno (2020) argued that teaching students BIM in higher education will reduce the time and money spent to upskill working professionals. However, P4 argued that a misconception exists about which skills should be taught at university and learned in the industry. Therefore, P1's recommendation to engage in more discussions with industry and academia is essential.

Similarly, Pillay *et al.* (2018) encouraged built environment faculties to collaborate and implement a strategy to teach the required BIM skills that meet the industry's demand. P1 and Kiprotich (2014) recommend that the drive come from the government and spread to universities. Moreover, Chimhundu (2015) stated that BIM would grow once higher learning institutions release BIM accredited qualifications. Strategic partnering was another initiative mentioned by P3 and confirmed by research (Aghimien *et al.*, 2020). However, strategic partnering is discussed in more depth in Section 6.4.2.

Promoting pilot projects:

Promoting pilot projects and case studies was an initiative proposed by several participants and by literature. P2 highlighted well-documented case studies as a sound approach to increase BIM uptake in the industry, and it was a recommendation specifically mentioned by P3. Similar to P3, Mtya (2019) also recommended that South African case studies could help establish guidelines and develop BIM standards and policies. Furthermore, Yan & Damian (2008) also proposed pilot projects to convince investors that BIM works. Pilot projects also formed the basis of Singapore's IDD strategy, as described in Section 3.1.4.

Developing standards:

Many participants argued that South African BIM standards would tremendously accelerate BIM adoption across the industry. P3 emphasised the development of local standards as a best approach to increase BIM uptake. P3, P6 and P8 mentioned that the industry needs a standard to eliminate confusion, which was also mentioned by previous research (Akintola *et al.*, 2017; Chimhundu, 2015; Mtya, 2019). Akintola *et al.* (2017) recommended that existing standards be used with a local annex, including South African requirements. Similarly, P6 recommended the ISO 19650 standard be adopted by South Africa and an annex be developed to address local differences. Akintola *et al.* (2017) noted the importance of such a

national standard being a jointly agreed-upon document from a selected group of industry professionals and BIM experts representing the private and public sectors.

Updating procurement systems:

The updating of the procurement system seemed to be a continuous discussion in the SACI and has been identified as a required solution to improve the industry for many years (Bowen *et al.*, 2012; Kwofie *et al.*, 2017; Windapo, 2017). Similarly, P8 recommended that the procurement systems be more collaborative such as an IPD approach. Similarly, Ogwueleka & Ikediashi (2017) recommended that the procurement system in South Africa be more collaborative and integrated to promote partnership and transparency. Froise (2014), Govender (2018) and Meno (2020) all emphasise the need for a more collaborative procurement system in South Africa. P5 specifically raised the opinion that contracts should accommodate the application of BIM systems and processes. Similarly, P7 suggested that contracts address IP and copyright concerns.

Developing software that meets South African needs:

The participants had contradicting views about the cost of software. However, considering that the bulk of the industry consists of small firms (see Table 5), P4's had a strong opinion. P4 reasoned that current software packages are aimed at large construction firms and are regarded as expensive and complex, especially for smaller firms. Therefore, P3 and P4 highlighted the need for suitable software packages to meet the specific needs of the South African industry. Similarly, Chimhundu (2015), Kiprotich (2014) and Mtya (2019) confirmed that smaller organisations struggle to implement BIM and that the available software does not meet their needs. Therefore, P4 suggested that addressing the software challenge and producing software that meets the South African market and industry needs is the best approach to increase BIM implementation.

Government initiatives:

Since 57% of construction projects in South Africa are publicly funded (Construction Industry Development Board, 2021) and due to the prominent role that the government plays regarding regulations and policies in the construction industry, the impact of government initiatives is a significant factor in BIM development. Therefore, the proposal of a BIM mandate on public projects was a common discussion point. However, P1 and P3 had a good recommendation – to produce a framework with hard and soft BIM mandates. “Soft” mandates meaning that BIM

is encouraged, promoted and preferred, and “hard” mandates meaning BIM is formally enforced. A framework would inform the industry of how the demand for BIM implementation would gradually increase. P3 noted that a mandate would encourage firms to adopt BIM.

Similarly, Froise (2014) and Harris (2019) recommend that the government consider mandating BIM. However, Akintola *et al.* (2017) remarked that the government could raise awareness through incentives and motivate BIM training and education before issuing a BIM mandate. Similarly, P1 reasoned that upskilling should come before BIM is mandated.

P1, similar to Meno (2020), recommend that awareness be raised through seminars and workshops. An interesting point was raised by P1, P4 and P5, which was not explicitly mentioned by the previous research about BIM in South Africa. They noted the digital transformation trends and predicted that the industry is moving to digital and smart cities. Therefore, these participants recommended that the government consider the value of intelligent cities and start collecting digital data. Incorporating smart cities was also part of the UK’s latest Digital Built Britain agenda (see Section 3.1.5). P5 argued that even though the government might not have the competency yet, they could just store the data while upskilling and setting up digital goals. P5 recommended that building plan submission be required in the form of paper hard copies, which is similar to Singapore’s BIM model-based e-submission system (McGraw Hill Construction, 2014a).

6.3 Objective 3

Identify the role-players responsible for facilitating BIM implementation across the SACI.

Objective 3 aims to identify the role-players in the industry that should drive, facilitate, accelerate and promote BIM implementation. The participants emphasised the importance of leadership and accountability when it comes to BIM implementation. P8 specifically mentioned that BIM implementation would fail without leadership. Although it was identified that leadership is essential to set the framework for BIM implementation, the participants suggested that effective BIM implementation still requires a collective effort from all role-players in the industry. Section 6.3.1 covers the interview findings, followed by the discussion of these findings compared with the literature in Section 6.3.2.

6.3.1 Summary of interview findings (Objective 3)

The primary role-players identified from the interview discussions were the government, the education sector, private organisations and software developers. These groups were identified by analysing the interview data and determining the essential groups needed to facilitate BIM implementation in South Africa. The role-players were divided according to these four groups. However, it should be noted that some organisations overlap between these main identified groups or fields. For example, the government plays the role of an asset owner, educator, regulator, policymaker and funding agency (ref. Ethiopia sketch).

To simplify, the government group consists of all government entities, municipalities, industry bodies, professional institutions, and voluntary associations. The reasoning behind this grouping was that these organisations all play a role regarding governance, regulation, legislation and professionalism. The education sector consists of organisations that provide training, education and research, such as universities, colleges, schools, training centres and research centres. These organisations could be publicly or privately funded. Private organisations refer to all construction project organisations that the government does not fund, such as architects, engineers and other consultants, contractors, clients and other organisations across the supply chain. Finally, software developers could also form part of educational institutions or private organisations. However, since they play a significant role regarding BIM implementation in the industry, they were put in a separate group.

The participants provided helpful information regarding strategies and initiatives, as mentioned in Section 6.2. However, they did not always mention who the responsible industry role-players were to execute these initiatives. Furthermore, when the discussions about roles and responsibilities arose, there were often contradicting arguments. Therefore, it was clear from the interviews that BIM implementation at a national level requires a collective effort between all industry role-players.

Therefore, the approach used the identified initiatives or strategies as summarized in Table 8 and logically assigned responsible industry stakeholders to these initiatives. Identifying the specific roles and responsibilities for industry role-players was a difficult task. Some roles and responsibilities were common knowledge, and the participants indicated who the role-players were. In contrast, other initiatives required interpretation and could require a joint effort between multiple role-players. Therefore, the initiatives that had obvious role-players were assigned to these role-players. The rest of the initiatives were assigned to a “collective effort”

group. The identified roles and responsibilities according to these identified industry role-players are identified in Table 9.

Table 9: BIM implementation role-players at an industry level

<p>Government</p> <ul style="list-style-type: none"> • Update construction contracts to accommodate BIM systems and processes (P5). • Develop a BIM implementation framework with hard and soft BIM mandates to give the industry direction (P1 and P3). • Start collecting data to develop digital and smart cities (P4 and P5). • Enforce building plan submissions in BIM models rather than paper hardcopies (P5). • Develop government subsidies to promote BIM adoption and upskilling in the industry (P1 and P2).
<p>Education sector</p> <ul style="list-style-type: none"> • Research the impact of BIM in South Africa (P6), including newly required skillsets and professions (P1). • University curricula could include technical BIM skills and processes, including collaboration, coordination, and communication (P1, P2, P3, P4, P6 and P8). Teach the ISO 19650 standard (P6). • Train professionals on how to produce, manage and exchange digital information (P6 and P8).
<p>Private organisations</p> <ul style="list-style-type: none"> • Strategic partnering between organisations to learn from one another (P3). • Further initiatives or responsibilities for private organisations are described in Section 6.4.
<p>Software developers</p> <ul style="list-style-type: none"> • Software suppliers could develop BIM software that suits the specific South African market and industry needs (P3 and P4). • Consider more affordable software packages that can perform basic BIM processes, suitable for smaller organisations in South Africa (P4). • Provide technical BIM support (P5).

Collective effort

- Make the government aware of the economic value of BIM (P4 and P5).
- Convince specifically asset owners and contractors of the value of BIM (P1, P2, P3, P4, P5, P6 and P9). For example, through case studies (P2), strategic partnering (P3) and conducting more research (P6).
- Initiate BIM discussions with the private sector, public sector, and educational institutions (P1).
- Raise awareness and educate the industry through BIM seminars and workshops (P1).
- Engage with the public to raise awareness and promote public participation through BIM (P7).
- Develop a national upskilling program (P2).
- Promote knowledge sharing initiatives where people across all fields of the industry could learn from one another (P1).
- BIM education and upskilling incentive on projects as part of the project's profit margin (P2).
- Pilot projects could be well documented to provide proof of concept and show the benefits of BIM (P2 and P3).
- Best practice standards could be developed using well-documented pilot projects (P3).
- Introduce common national standards of information exchange and the use of software to eliminate confusion in the industry (P3, P6 and P8).
- Adopt the ISO 19650 standards and include a national annex to meet the South African requirements (P6).
- Construction contracts could address IP and copyright concerns (P7).
- Consider more collaborative procurement methods such as IPD (P8).
- Learn from other countries and use their BIM implementation methods to build a BIM implementation strategy in South Africa (P8).
- Engage with educational institutions and the industry to discuss the newly required job roles and skillsets (P1).

6.3.2 Discussion

Government:

The specific government initiatives, such as creating awareness, upskilling incentives and government mandates, were discussed in Section 6.2.2. For Objective 3, only the role of the government is discussed here. Froise (2014) and Akintola *et al.* (2017) highlighted government support's importance in guiding and promoting BIM implementation in South Africa. P1, P2 and P5 had similar opinions. The role of the government or public sector is made clear in Figure 10, stating that the government plays the role of being an initiator and driver, regulator, educator, funding agency, demonstrator and researcher. These roles become evident when considering the recommendations provided by the participants in Table 9. For example, since the government is the regulator, it could update construction contracts as proposed by P5. P5's comment was also mentioned by Meno (2020). Meno (2020) recommended that government procurement specialists explore alternative procurement systems that promote the use of technology.

Furthermore, firms need guidance on best practices, according to P4. Therefore, the government could guide best BIM practices through industry bodies such as the CIDB and the CBE. Similarly, Froise (2014) recommended that the government bodies such as the CIDB release more information about BIM to educate the industry. However, this requires research. Therefore, Meno (2020) noted that more funds should be allocated toward research and development. For example, the government could create subsidies to promote BIM adoption and education, as proposed by P1 and P2. However, Kiprotich (2014) remarked that more funding would only become available when the industry becomes fully aware of BIM.

P4 and P5 noted that the government should become aware of digital and smart cities trends and move toward these goals. P5 recommended that the government start collecting digital data by enforcing building plan submissions in the form of BIM models rather than paper hard copies. Singapore already did this in 2008 (McGraw Hill Construction, 2014a). P1 reasoned that such a sudden change could fail and recommended the government develop a framework with hard and soft BIM mandates to ease the transformation process. Similarly, the UK took a gradual approach to become the BIM implementation leader, as discussed in Section 3.1.6.

Education Sector:

The education sector plays a vital role, next to the government, according to P1. They are responsible for research (P1 and P6), educating students and upskilling the industry. The majority of the participants noted that university curricula should be updated to deliver BIM competent graduates, and this was also mentioned by Pillay *et al.* (2018) and Tabesh (2015). In addition, the education sector is responsible for keeping up with industry trends and decreasing the gap between skills supply and demand, which was a common challenge in the SACI, as Windapo & Cattell (2013) noted. P6 and P8 remarked that the new skills required are those of producing, managing and exchanging digital information.

Private organisations:

Private organisations have to implement BIM on projects while ensuring their business remains profitable. Therefore, it is these organisations that have to require the skills to implement BIM. An initiative noted for these firms is to partner with other firms and learn from each other. Strategic partnering was recommended by P3 and was mentioned by previous research such as Aghimien *et al.* (2020) and Froise (2014). More guidance to private organisations is provided in Section 6.4.

Software developers:

According to Akintola *et al.* (2017), software vendors are the current drivers of BIM in South Africa due to the lack of government BIM intervention. Furthermore, their importance to BIM implementation cannot be underestimated since BIM is based on using the technology provided by these software developers. For example, Singapore realised the importance of software development, and part of their IDD plan was to develop digital platforms that suit Singapore's construction firms (Building and Construction Authority, 2018). Similarly, P4 suggested that international software does not suit the local market and industry needs and therefore highlighted the need to develop software that suits South African firms. Furthermore, software developers could provide BIM training for BIM use, as Kiprotich (2014) noted.

6.4 Objective 4

Provide practical guidance for South African organisations to implement BIM in terms of best practices.

Since there are no national standards or guidelines to assist organisations to implement BIM in South Africa, this objective aimed to give organisations some guidance. Construction industry organisations differ in type (architects, asset owners, engineers, other consultants, contractors, project managers, subcontractors and suppliers) and work on various projects (civil works and buildings). However, all these organisations play a role in enabling BIM processes to be carried out efficiently.

Although there is an abundance of guidelines and standards on BIM implementation, such as the NZ BIM Handbook, the ISO 19650 standards and Singapore's BIM adoption guidelines, to name a few, there exists no national BIM standard or guideline for South Africa. The guidelines for other countries could be adapted to suit the South African context. However, before the industry has accepted national standards and guidelines, the findings of this objective could be used as guidance and assist with the development of industry standards and guidelines. These findings are purely based on the interviews, and more research needs to be done to provide the industry with specific best practices that guarantee effectiveness. Nevertheless, the interview findings produced helpful findings that could assist firms in BIM implementation.

6.4.1 Summary of interview findings (Objective 4)

This section provides a summary of the interview findings, which is divided into three tables. The first table (Table 10) summarises the general guidance for firms to implement BIM within the **organisation**, as described by the participants. These guidelines are not aimed at a specific organisation type or size but are general suggestions that could be considered by any of the typical construction project stakeholders. The second table (Table 11) summarises the best practices proposed by the participants to implement BIM within a **project**. Finally, Table 12 concludes the interview findings for this objective where specific guidance is given from the interview participants to specific **project stakeholders**. The content of these tables is discussed in Section 6.4.2.

Table 10: General best practices within an organisation

<p>Determine the business value of BIM</p> <ul style="list-style-type: none"> • Examine available technologies and consider adopting digital processes to improve the business (P6). • Examine the ISO 19650 standard that includes a defined work list and requirements per job title to discover the firm's BIM role in projects (P6). • Discover the business value of BIM for the specific business since each business benefits differently from using BIM (P6 and P8). • Examine case studies and compare BIM projects with non-BIM projects. (P2, P4 and P7). Calculate cost savings related to the reduction in RFI's (P4). Calculate the savings due to fewer rework and change orders (P7). • List the organisation's most significant expenses and discover how these could be reduced using BIM (P6).
<p>Developing a strategy to implement BIM in the organisation</p> <ul style="list-style-type: none"> • Develop a digital strategy or BIM strategy to improve specific business operations (P6). Focus on improving operational effectiveness before improving strategic competitiveness (P4). • A BIM strategy could be clear, take a stepped approach and have specific goals and objectives (P2, P5 and P6). • One of the first objectives could be becoming entirely digital and moving away from paper (P2 and P8). • A strategy should be communicated to everyone in the organisation (P1, P2, P5 and P6).
<p>Acquire external assistance</p> <ul style="list-style-type: none"> • Consult with BIM consultants, software developers or partner organisations to assist with the change management or transformation (P2 and P5). • Initial guidance is needed to develop a BIM strategy, choose the correct technology, and develop BIM workflows and policies (P2, P3 and P6). In addition, BIM processes should align with business objectives (P2). • Technical BIM support is needed, especially while the organisation is still upskilling (P2 and P5). • Consider strategic partnering with other organisations to learn from one another (P3).

Sound change management practices

- The change management process and the restructuring of firms play a huge role when undergoing digital transformation (P1 and P6).
- Take small steps to gradually increase the organisation's BIM maturity and capability (P4).
- Develop clear guidelines and standards to guide people in the organisation on the change management process (P2).
- When restructuring the firm, strategically place individuals in positions where their knowledge and expertise is optimally utilised (P9). For example, consider younger individuals that are more technically capable and older individuals that have more experience.
- Business owners and senior management buy-in to the BIM implementation process are vital to the success of the process (P2, P3 and P8).
- Organisations could have at least two BIM champions. One that drives BIM at a senior level and one at a junior level (P4).

Initiate a pilot project

- Pick a project and develop specific BIM goals and milestones for the project (P8).
- Once there is a proof of concept, more buy-in will be gained from the rest of the firm and other project stakeholders (P3).
- Implementing BIM on a project is the best way to learn BIM (P1).
- Pilot projects could serve as a framework for developing best practice guidelines and standard approaches that guarantee effectiveness (P3).
- See Table 11 for best practices within a project.

*Table 11: General best practices within a project***Setting up the project BIM roles and responsibilities**

- All project stakeholders should be made aware of the value of BIM and buy into the BIM process. (P8)
- Clear BIM goals and objectives from the onset of the project (P1 and P6).
- Decide on BIM roles and responsibilities early on in the project (P5).
- Formal documentation should describe the quality and quantity of information produced and how this information is exchanged (P1, P2, P3 and P6). These documents could include a BEP, EIR and PIR (P1). The ISO 19650 standard could guide the documentation and establish the project stakeholders' BIM roles and responsibilities (P3).
- Clients could enforce BIM deliverables to provide a structured BIM environment (P1 and P3). They benefit from the digital models used in the operational phase (P1, P4 and P5).
- A dedicated BIM coordinator should ensure that all project stakeholders carry out their respective BIM roles and responsibilities (P2 and P8).
- A data manager should ensure the quantity and quality of information are produced according to the BIM requirements (P2).

General sound practices within a project

- Project stakeholders should collaborate instead of working on multiple BIM models leading to repetitive work and outdated information (P3, P4 and P8).
- Setup a BIM user forum for the project team for open BIM discussions (P6).
- The contractor should be involved in the project as early as possible to benefit from the BIM process (P8).
- The digital BIM model schedule should run ahead of the physical construction schedule (P8).
- Refrain from pseudo-BIM, where BIM leads to additional work instead of work reduction (P8). (Pseudo-BIM is explained in Section 4.2.5.)

Table 12: Recommendations for specific project stakeholders

Architects <ul style="list-style-type: none"> Consider acquiring BIM management and coordination skills to guide the information management process and establish the required BIM deliverables in a project (P3 and P7).
Asset owners <ul style="list-style-type: none"> Enforce BIM requirements and deliverables using formal documentation (P3 and P5). Use ISO 19650 as guidance for OIR, EIR, PIR and AIR (P1). Collect digital data as part of future digital cities and smart cities (P5). Consider how BIM could improve asset management processes such as financing, preventative maintenance, future planning, renovations and utility management (P5). Examine CMMS and CAFM applications for the operational phase of assets (P3).
Other consultants <ul style="list-style-type: none"> Improve operational processes and quality of work using BIM (P6). Consider delivering BIM services such as BIM modelling, BIM management or coordination, BIM consulting, digital twin development or green building services (P6 and P9).
Contractors <ul style="list-style-type: none"> Determine the benefit that BIM brings for the business and use BIM regardless of the client's requirements (P9). Think of BIM as a cost reduction as opposed to a cost addition (P6). Consider where the highest costs for the organisation are and how this can be reduced using BIM. For example, consider the cost of manhours, unused machinery and equipment, materials arriving late or early, accidents, RFI's, scheduling, site planning, calculating quantities (P6). Consider hiring BIM modellers and BIM managers to upskill the organisation. Alternatively, subcontract to BIM consultants to carry out the BIM processes (P9).
Project managers <ul style="list-style-type: none"> Acquire the competency to facilitate the BIM process on projects (P3).
Subcontractors and suppliers <ul style="list-style-type: none"> Suppliers could digitize their product data on BIM libraries (P3). Subcontractors could acquire BIM software to develop fabrication models (P3).

6.4.2 Discussion

General best practices within an organisation:

The best practices shown in Table 10 are based on the participant's responses and are not tested to guarantee effectiveness, such as the ISO 19650 standards. However, these best practices are suggestions that could be considered by firms wanting to adopt BIM. Using the thematic analysis process of Braun & Clarke (2006), the themes for organisational best practices were grouped according to the following topics:

1. *Determine the business value of BIM:* Each organisation benefits from BIM differently, as described in Section 2.1.2 and mentioned by P6 and P8. Furthermore, as mentioned by P8, once the benefits are realised, it would create a drive in the organisation. The participants provide some helpful basic recommendations to determine the business value of BIM are given in Table 10. However, there are several studies and reports which provides more detailed recommendations, such as PwC's (2018) "BIM level 2 benefits measurement" report and "the business value of BIM for owners" by (McGraw Hill Construction, 2014b). These could be studied as further guidance on quantifying the benefits of BIM or determining the ROI.
2. *Develop a BIM strategy:* At an organisational, project and industry level, a strategy with clear goals was critical to the success of BIM implementation. Similarly, Sahil (2016) recommended that the organisation develop BIM goals and objectives to determine the technology requirements. P4 urged that organisations first focus on improving their operational effectiveness before improving their strategic competitiveness. P4 reasoned that operational effectiveness yield direct cost savings and are easier to obtain than improving strategic competitiveness and expanding the business. As mentioned by P2 and P8, these operational improvements could be to become digital and move away from paper. Similarly, the advantages of digitalisation were highlighted by Sahil (2016), and they emphasised that adequate planning should be done when undergoing a digital transformation.
3. *Acquire external assistance:* The need for external assistance when organisations implement BIM is critical, especially at the start, as indicated by P2, P3 and P6. The participants suggested that assistance could come from BIM consultants, software developers or partner organisations. Similarly, Aghimien *et al.* (2020), Froise (2014) and Vidalakis *et al.* (2020) recommended strategic partnering between organisations.
4. *Sound change management practices:* The participants emphasised that the change management practices could not be underestimated. Arayici *et al.* (2012) confirmed the importance of change management in BIM adoption. The importance of buy-in from the

firm was highlighted by P2, P3 and P8 and the research of Vidalakis *et al.* (2020). Furthermore, the importance of communication was another sound practice. A valuable suggestion noted by P9 was to optimise the restructuring of firms. P9 recommended that individuals be strategically placed in positions where their knowledge and expertise is optimally utilised. For example, older, experienced individuals could be partnered with younger, technical individuals.

5. *Initiate a pilot project:* Instead of sending employees on expensive training courses, the participants recommended that firms take a leap of faith and start to implement BIM on a project. P1 noted that this is the best way to learn BIM. The idea of pilot projects was one of Kouch's (2018) recommendations and formed a key part of Singapore's IDD strategy (Building and Construction Authority, 2018).

General best practices within a project:

The best practices mentioned in Table 11 are aimed at a project environment where different organisations work together to execute the project. The ISO 19650 standard is seen as the current international best practice for executing BIM within a project. However, since South Africa has not adopted the ISO 19650 or any other standard, there is still confusion about the best way to implement BIM in a project. Furthermore, the lack of skills in South Africa concerned some interviewees whether such high detailed standards such as ISO 19650 could be followed in South Africa. Therefore, Table 11 provides a list of rough guidelines as proposed by the interview participants.

The central theme identified as a best practice regarding a BIM project was setting up clear roles and responsibilities from the project's onset. P9 explained that BIM projects typically start later than traditional projects since more emphasis is put on the design and planning stage. However, P9 argued that the construction stage is much quicker, and the initial time lost is made up later in the project, with less rework, change orders and delays. P3 remarked that the ISO 19650 standard could guide the setting up of BIM roles and deliverables. P1, P3 and P5 recommended that clients enforce the deliverables to provide a structured environment to implement BIM since they benefit from obtaining the digital models in the operational phase. Furthermore, the importance of a dedicated BIM coordinator was seen as a critical full-time role to ensure that the stakeholders' BIM roles and responsibilities are executed.

Other sound practices within a project mentioned in Table 11 included setting up a BIM user forum, involving the contractor early on in the project, refraining from silo BIM and pseudo-BIM, and the digital model should run ahead of the physical model.

Recommendations for specific project stakeholders:

Table 12 describes recommendations from interviewees as applicable to specific organisation types. Since BIM implementation involves a change to the way projects are executed, project organisations' roles and required skillsets could change. For example, Froise (2014) identifies the opportunity for new companies to provide BIM training or BIM consulting to South African firms. Similarly, P6 and P9 recommended that consultants consider delivering BIM services such as BIM modelling, BIM management or coordination, BIM consulting, digital twin development or green building services. The change in the roles and skillsets of project stakeholders is out of the scope of this research. However, some recommendations are provided to different organisations in Section 7.3.

6.5 Proposal

The study aimed to develop a proposal to facilitate BIM implementation across the SACI. The four objectives of the study enabled the researcher to obtain a holistic perspective on the phenomenon. First, a better understanding was gained of the challenges to BIM implementation in South Africa. Second, proposed solutions to overcome the challenges, in terms of strategies and initiatives, were found and discussed. Third, the main industry role-players responsible for facilitating BIM implementation were identified. Finally, practical BIM implementation was discussed, and best practices were identified for firms implementing BIM.

The findings discussed above provide insight towards a proposal to facilitate BIM implementation across the SACI. The three sections discussed for the proposal include leadership, strategy, and roles and responsibilities.

6.5.1 Leadership

Throughout the literature and the interviews, it was found that leadership is vital for the success of BIM implementation in the industry. However, there was some confusion about who should lead the BIM initiative. The main role-players required to facilitate BIM implementation were divided into four groups: the government, the education sector, private organisations, and software developers. It was found that effective and widespread BIM implementation requires a collective effort between these role-players. However, these identified groups consist of different organisations with different interests and funding, making it challenging to collaborate and work together towards one common goal.

Considering what was done by other countries regarding leadership, the solution becomes clear. These countries had BIM committees or councils responsible for accelerating, regulating, and promoting BIM in the country. For example, Australia established an Australian BIM Advisory Board, Ireland a National BIM Council, the UK a BIM Task Group and the US a National BIM Program Steering Committee. It seemed that most of these committees, councils or boards consisted of experts and professionals representing different fields of the industry. A similar approach could be applied in South Africa by forming a group of experts representing the main industry role-players. Similarly, Mtya (2019) proposed the formation of a BIM advisory board.

This group could be developed as a board, a committee, or a task group, but it is called the South African National BIM Council (SANBC) for the proposal. The SANBC could be separate from the existing industry bodies, professional institutions, and voluntary associations, such as CIDB, CBE, or SAICE. However, these industry bodies could have representatives in the SANBC, and the initiatives proposed by the SANBC could be reflected and executed by these industry organisations.

6.5.2 Strategy

Once a BIM council is established, a clear BIM strategy or action plan with initiatives could be developed to guide the industry. For example, Ireland's NBC developed a "digital roadmap" to guide the industry. This strategy could include clear goals to develop the construction industry, such as those set by the UK in their Government 2025 strategy. However, the UK's latest goals in their Digital Built Britain agenda includes goals reaching broader than just the construction industry and involves a digital agenda toward smart cities and IoT, among other things. South Africa could consider adopting some aspects of these global strategies towards a South African BIM strategy while considering the nature of the SACI.

Pilot projects could form the central part of a national BIM strategy since it was a common theme in the interview discussions, and it was part of Singapore's IDD strategy. Well documented pilot projects could provide proof of concept while upskilling the industry. Furthermore, the challenges to BIM implementation and the solutions to overcome these challenges would become more apparent, guiding the industry on the best way forward. Pilot projects could be monitored through research. The research could update the BIM strategy, develop new guidelines and standards, and further guide the industry.

6.5.3 Roles and responsibilities

Leadership and strategy could give the industry direction. However, the strategy needs to be executed and monitored. Therefore, the main industry role-players could be assigned specific roles and responsibilities aligned with the BIM strategy. The proposed initiatives falling under the main industry role-players are shown in Figure 13. These initiatives are adopted from the findings of the interview discussions. The layout of Figure 13 suggests that the SANBC represents the SANBC leading the four main groups of industry role-players. The principal roles are discussed below.

South African National BIM Council (SANBC)			
<ul style="list-style-type: none"> • Lead BIM implementation while guiding industry stakeholders in their role. • Act as the sole source of information released about BIM in the South African construction industry. • Develop a national BIM implementation strategy and action plan. • Develop BIM standards. • Raise awareness through discussions, seminars and workshops. • Initiate and monitor BIM incentives. • Initiate pilot projects and document them as case studies. 			
Government	Education sector	Private organisations	Software developers
<ul style="list-style-type: none"> • Develop a BIM implementation framework with hard and soft mandates. • Update contracts and procurement systems. • Collect data to develop digital and smart cities. • Adapt regulations and policies. • Develop incentives towards BIM education such as subsidies and tax reliefs. 	<ul style="list-style-type: none"> • Develop a national upskilling and education programme. • Conduct research on BIM in South Africa, including the industry's skill demand. • Update university curricula to release BIM competent graduates. • Upskill the industry. 	<ul style="list-style-type: none"> • Determine the business value of BIM and develop an organisational strategy to implement BIM. • Implement BIM and upskill the organisation. • Partner with other organisations. 	<ul style="list-style-type: none"> • Provide software that matches the South African industry and market needs. • Provide technical BIM support.

Figure 13: Proposal for the main industry role-players (author)

SANBC:

The primary purpose of the SANBC could be to lead BIM implementation and guide the industry. From the interviews, it was found that the industry needs a trusted source of information about BIM. The SANBC could be in the best position to release information about BIM to the industry. This information could include a national BIM strategy, a BIM mandate framework, a national upskilling strategy, BIM guidelines, a national BIM handbook, BIM standards and a BIM library. However, this information needs to be adequately regulated by

the SANBC to ensure that the industry is not misguided and accepts the SANBC as the single source of truth for the SACI. Chimhundu (2015) also emphasised the need for a single source that provides BIM information in South Africa, such as BIM libraries, data exchange frameworks and BIM guidelines.

The initiatives that require more than one industry role-player were allocated to the SANBC in Figure 13. Similarly, Akintola *et al.* (2017) reasoned that a national BIM standard requires collective input from all industry stakeholders from the public and private sectors. Therefore, the selection process and criteria of the SANBC representatives should be carefully decided. For example, one of the criteria could be that there has to be an adequate representation of all significant industry role-players in the SANBC. Consequently, appropriate representation would ensure that the roles and responsibilities of these role-players are executed, and the interests of these role-players are considered. Furthermore, from the interview discussions, it was determined that much of the skills and expertise in South Africa lies in the private sector. Therefore, incentives could be considered to attract professionals into the SANBC.

Government:

To simplify, the government group consists of all government entities, municipalities, industry bodies, professional institutions, and voluntary associations. The reasoning behind this grouping was that these organisations all play a role regarding governance, regulation, legislation and professionalism. Being the country's largest asset owner, the government could develop digital and smart cities. Therefore, the government group was given the role of developing a BIM mandate and requiring BIM deliverables on projects. Furthermore, they would have to consider promoting more collaborative contracts and procurement systems in the industry. Regulations and policies could be adapted accordingly. Industry bodies, professional institutions and voluntary associations could educate the industry on these new regulations and policies. In addition, the government could develop incentives to promote BIM education and upskilling, such as subsidies and tax reliefs.

Education sector:

The education sector consists of organisations that provide training, education and research, such as universities, colleges, schools, training centres and research centres. Regulatory bodies could also play a role in the education sector, such as the Construction Education

Training Authority (CETA). Educational institutions could be publicly or privately funded. However, they all play a role in educating and upskilling. Therefore, these organisations could have guidance in national education and upskilling programmes, which involve updating curricula to deliver skilled BIM professionals. Furthermore, the SANBC could engage with universities to develop BIM research programmes to assist the BIM strategy. For example, the United States awarded Penn State University a national BIM research programme to increase BIM research and develop BIM guidelines and standards (BIM Industry Training Group, 2016).

Private organisations:

Private organisations refer to all construction project organisations that the government does not fund, such as architects, engineers and other consultants, contractors, clients, and other organisations across the supply chain. These organisations are responsible for discovering how their project role contributes to BIM implementation and aligning their business goals accordingly. Although there is no national leadership such as the SANBC yet to provide firms with guidance in BIM standards that guarantee effectiveness, organisations could start implementing BIM. The general guidance provided in Section 6.4 could be used to help firms. For example, one of the recommendations was for these firms to partner with other organisations.

Software developers:

Finally, software developers play a significant role in BIM implementation since they provide the software used to carry out BIM processes. From the interview discussions, South African firms, especially smaller firms, find the existing software packages expensive and too complex. The suggestion was that software developers develop software packages that are more basic and less expensive to meet the South African market and industry needs. However, software developers run a business and have an established market. Therefore, an incentive for software developers could be developed to encourage them to meet the South African market and industry needs. For example, the government could take a similar route as Singapore and raise a tender to develop software that suits South Africa's needs. Alternatively, the government could subsidise the cost of software licenses to allow smaller firms in South Africa to implement BIM. There is certainly more research required on the demand and supply of software in the SACI.

7 Conclusion and recommendations

7.1 Conclusion

The research problem was that there is not industry-wide, effective BIM implementation in the SACI. While the global construction industries are utilising BIM, South Africa still lacks widespread and effective BIM implementation across the industry. Therefore, the study aimed to develop a proposal to facilitate BIM implementation across the SACI.

A literature review covered the theoretical background of BIM and a review of the related global and local literature. First, the South African literature was thoroughly studied to better understand the challenges faced in South Africa regarding BIM implementation and the solutions proposed to mitigate these challenges. Then, an industry analysis was conducted covering the global BIM implementation strategies among six countries, followed by a deeper description of the nature of the SACI.

The methodology was exploratory and entailed two main phases. Phase one was regarded as a preliminary phase where the researcher gained a better understanding of the phenomenon, which entailed literature, webinars, short courses, educational videos, and discussions with industry professionals. The first phase formed a basis for the second phase. Phase two entailed conducting semi-structured interviews with nine BIM experts that have a good understanding of the SACI. The interviews were manually analysed using thematic analysis. The interview findings were then compared with the literature and discussed. Finally, the researcher developed a proposal as guidance for the industry to facilitate BIM.

The first objective was to “*gain an understanding of the challenges associated with BIM implementation across the SACI*”. Firstly, a thorough literature review was conducted on the challenges faced by the SACI regarding BIM implementation. Next, the findings from previous research were collected and compiled. Then, the interview discussions enabled the researcher to explore further the current challenges faced by the industry. The main challenges in the industry regarding BIM implementation were found to be related to educational, cultural, legal, financial, and governmental aspects (refer to Table 7). Finally, the challenges were discussed and compared with the literature (Section 6.2.2). As a result, a better understanding of the challenges was gained.

Objective two was to “*identify possible solutions in terms of initiatives and strategies to facilitate and promote BIM implementation across the SACI*”. Firstly, a thorough literature review enabled the researcher to collect the industry solutions proposed by previous researchers. Then, the interview discussions allowed the researcher to find additional initiatives and strategies and discuss the solutions applicable to South Africa. The interview findings were summarised in Table 8 and compared with the literature in Section 6.2.2. A range of possible strategies and initiatives to facilitate and promote BIM implementation were identified. The strategies and initiatives were arranged under the main identified themes: raising awareness, education and training, promoting pilot projects, developing standards, updating procurement systems, developing software that meets South African needs, and government initiatives.

The third objective was to “*identify the role-players responsible for facilitating BIM implementation across the SACI*”. The interview findings and discussion for this objective is found in Section 6.3. The study found that all organisations and entities in the construction industry play a role in BIM implementation. However, the main role-players were divided into four industry groups, namely, the government, the education sector, private organisations, and software developers. In addition, industry bodies, municipalities, professional institutions and voluntary associations were considered part of the government group since they also regulate the industry.

The final objective was to “*provide practical guidance for South African organisations to implement BIM in terms of best practices*”. This objective aimed at providing general guidance for South African **organisations** to start implementing BIM since there are no national standards or guidelines specifically for South Africa yet. The general guidance involved key points found from the analysis of the interviews (refer to Table 10). This guidance involved the following main categories:

- Determine the business value of BIM.
- Developing a strategy to implement BIM in the organisation.
- Acquire external assistance.
- Sound change management practices.
- Initiate a pilot project.

Furthermore, guidance to implement BIM in a **project** were summarised in Table 11. In addition, specific guidance was given to specific **project stakeholders** in Table 12. The content of these tables is discussed in Section 6.4.2 and compared with the literature.

Finally, the project's aim was achieved with a proposal made to facilitate BIM implementation across the SACI (refer to Section 6.5). The proposal entailed three key concepts, namely, leadership, strategy, and roles and responsibilities. For leadership, it was proposed that a BIM council be established consisting of professionals and experts representing the key BIM role-players in the industry. It was highlighted that a clear strategy is required to guide the SACI to implement BIM. Finally, the key role-players in the industry were assigned specific roles and responsibilities to facilitate BIM implementation across the SACI. This research contributes to BIM development in the SACI and could be used for future research on national BIM implementation strategies.

7.2 Valuable findings

The findings and discussions in Chapter 6 provide the reader with a holistic picture of the research outcomes. However, many of these findings have been previously mentioned by research. Therefore, this section provides the reader with the significant findings that were not specifically highlighted by previous research in South Africa. These findings are not necessarily regarded as more important than the findings in Chapter 6.

- The available software in South Africa does not meet the requirements of the SACI and market needs. There is a huge scope for further research on this topic. However, if this is proven as a fact, it is a major challenge in the SACI. Some solutions that were identified were that software providers could consider developing simpler software that can perform the basic BIM processes and come at a lower price. The majority of the construction industry consists of small organisations, and they could be the target market.
- The risk of theft and vandalism is a challenge in South Africa, with specific reference to technology used on site.
- The high costs associated with upgrading the network connection infrastructure is another South African challenge. Effective BIM processes (live communication) would fail on rural sites where there is no internet connection.
- Under government initiatives, a key finding was that the government could develop a smart city agenda such as the UK and start collecting digital data of infrastructure. This was a strong point and recommendation for private clients as well since most of the benefits of BIM and digitisation are found in the operation and maintenance phase of a

built asset (buildings and civil infrastructure). One suggestion was clients require that designs be submitted in BIM models instead of only on paper hardcopies.

- The value of BIM could be calculated through studying case studies. For example, a cost factor could be assigned to RFI's and change orders. By calculating the change in RFI's and change orders in BIM projects, a value could be obtained. This method would require many assumptions and it would not take all the benefits of BIM into account. However, it should already provide a clear indication of the value of BIM.
- There is a growing demand for digitally skilled professionals, especially regarding BIM modelling and software development.
- One of the most valuable findings was the recommendation that organisations should move away from paper and attempt to carry out their tasks digitally. In some cases, using paper is more convenient and would likely never change. However, there are many project tasks that can be performed without paper.
- Firm restructuring is very important when implementing BIM in an organisation. One of the recommended strategies was to pair young, technology competent individuals with older, less technology competent employees. This way, they could learn from each other.

7.3 Recommendations

Some recommendations were already mentioned as part of the findings in Section 6. Therefore, this section presents the additional recommendations for the main industry role players and recommendations for further research.

7.3.1 Main industry role-players

In addition to the proposal to facilitate BIM implementation, the recommendations for the main industry role-players include:

1. The government: Determine the value of BIM, digital cities and smart cities. Develop the required mandates, policies, and regulations to guide and lead the industry.
2. The education sector: Conduct more research on BIM, update university curricula to meet industry demands, teach the ISO 19650 standards. In addition, educate the industry on BIM and digital processes.
3. Software developers: Determine exact industry and market needs in South Africa and develop suitable software solutions.

4. The collective effort of the industry:
 - Raise awareness about the value of BIM.
 - Educate the industry through BIM case studies, seminars, workshops, strategic partnering and conducting more research.
 - Initiate BIM discussions with the private sector, public sector, and educational institutions.
 - Engage with the public to raise awareness and promote public participation through BIM.
 - Promote knowledge sharing initiatives where people across all fields of the industry could learn from one another.
 - Adopt the ISO 19650 standards as a national standard and include a national annex to meet the South African requirements.
 - Consider more collaborative procurement methods such as IPD.
 - Learn from other countries and use their BIM implementation methods as a basis for a BIM implementation strategy in South Africa.
5. Private organisations in general:
 - Determine the business value of BIM.
 - Developing a strategy to implement BIM in the organisation.
 - Acquire external assistance.
 - Conduct sound change management practices.
 - Initiate a pilot project.
6. Architects: Consider acquiring BIM management and coordination skills to guide the information management process and establish the required BIM deliverables in a project.
7. Asset owners:
 - Consider how BIM could improve asset management processes such as financing, preventative maintenance, future planning, renovations and utility management
 - Collect digital data by enforcing BIM requirements and deliverables using formal documentation. ISO 19650 could be used as guidance.
8. Other consultants: Consider delivering BIM services such as BIM modelling, BIM management or coordination, BIM consulting, digital twin development or green building services.
9. Contractors: Consider digitalising the firm and adopt software that could reduce the organisation's largest operational expenses.

10. Project managers: Acquire the competency to facilitate the BIM process on projects.
11. Subcontractors: Acquire BIM software to develop fabrication models.
12. Suppliers: Digitize product data on BIM libraries.

7.3.2 Future research

The proposal to facilitate BIM implementation mentioned the need for investigating the impact of BIM, the skills demand in the industry and the software demand for the industry. In addition, the recommendations for future research include:

- In addition to the industry skills demand, research could be done on how these required skills will change in the future, to prepare for future changes and required skillsets.
- Determine the best way to measure BIM maturity in South Africa comparable to other countries and BIM maturity in an organisation comparable to other organisations.
- Measure BIM maturity in South Africa and continuously assess the maturity increase amongst different organisations and project types.
- Continuously research if the available software and technology in the market meet the needs of South African firms, especially smaller firms with limited budgets.
- Best practices in South Africa to implement BIM in an organisation, in a project and the industry. Case studies could form an essential part of this research.

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Appendix 1 – Interview guide

1. What is your current **understanding** of the concept of BIM?

BIM adoption and implementation (organisation, project, and industry level)

2. What is your perspective on the main **challenges** in South Africa associated with optimal/effective BIM implementation?
3. What **strategies** or **initiatives**, do you think, will promote effective BIM implementation (BIM at a high maturity)?
4. Who (i.t.o. people or institutions) do you think are responsible to **drive** BIM implementation? What are their roles?
5. What do you think are the **best practices** to follow when adopting and implementing BIM? What are the worst practices to follow?

Focus on practical BIM adoption and implementation at an organizational level:

6. What kind of **assistance** do organisations need to effectively adopt and implement BIM in terms of *technology*, *people*, and *policies*? (Or undergo digital transformation)
7. In your opinion, how can we quantify the **benefits** of BIM? (Consider all project stakeholders)
8. Do you have specific **recommendations** for project stakeholders to start adopting BIM or move up the BIM maturity ladder?
 - a. Architects.
 - b. Clients.
 - c. Consultants.
 - d. Contractors.
 - e. Project managers.
 - f. Sub-contractors.
 - g. Suppliers.
 - h. Others.

Focus on BIM adoption and implementation at an industry level

9. What do you think are the **roles** of the following institutions in promoting/accelerating/facilitating optimal, industry-wide BIM implementation?
- a. Government.
 - b. Regulatory bodies.
 - c. Policymakers.
 - d. Professional institutions / Industry bodies.
 - e. Educational institutions.
 - f. Software developers.
 - g. Other.
10. What, in your opinion, would be the best **approach** to facilitate or accelerate effective and widespread BIM adoption in South Africa?

Closing question:

11. Any final thoughts on the **future** of BIM and digital transformation in South Africa?

